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ORIGINAL ARTICLES.

I.—Woodwardian Museum Notes: Brachymetopus Strzeleckii, McCoy, 1847.

By F. R. Cowper Reed, M.A., F.G.S.

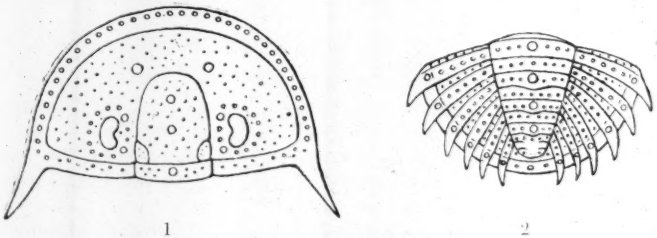
THE genus *Brachymetopus* was founded by McCoy in 1847,[1] and the generic characters were drawn from the Australian species *Br. Strzeleckii*, McCoy, which was at the same time described. The specific characters of this form were very briefly given, the leading features having been mentioned in the diagnosis of the genus. Dr. Henry Woodward[2] in 1884 gave a new summary of the generic characters differing somewhat from that originally furnished by McCoy, being modified in such a way as to include the European or British species, *Br. ouralicus*, De Vern., *Br. Maccoyi*, Portl., *Br. discors*, McCoy, and *Br. hibernicus*, Woodw. The original type-specimens of *Br. Strzeleckii* used by McCoy (op. cit.) in drawing up the description of the genus, and figured by him at the same time, are in the Woodwardian Museum, to which they were presented in the year 1844 by the Rev. W. B. Clarke. They come from the Carboniferous Shale of Dunvegan, New South Wales.[3] The specimens comprise three complete head-shields, two of which are hollow impressions and one a cast, and portions of three or four others; there are also three casts of complete pygidia, one perfect impression, and fragments of two others. This material demands a fuller description of the specific characters than McCoy furnished, particularly as this type-form of *Brachymetopus* shows features differing in several respects from those of the better known European species ascribed to the same genus. McCoy's description (op. cit.) of the species was as follows:—"Glabella widest at the base, with one very minute, obscurely marked, cephalothoracic furrow at the base on each side; all the segments of the pygidium with an irregularly tuberculated ridge along the middle; lateral segments forming large tubercles where they join the thickened limb, opposite each of which is a short slender spine projecting from the margin."

[1] McCoy: Ann. Mag. Nat. Hist., xx (1847), p. 229, pl. xii, figs. 1*a*, 1*b*.

[2] Henry Woodward: Mon. Brit. Carb. Trilob. (Palæont. Soc.), 1884, p. 46.

[3] The plants in this collection have lately been re-described by Mr. E. A. Newell Arber, Q.J.G.S., lviii (1902), pp. 1–26.

This description may be amplified as follows (using only the type-specimens) :—Head-shield semicircular, moderately convex, with strong raised rounded border increasing slightly in width towards the front, and separated off by a deep furrow. Genal angles furnished with slender divergent smooth spines, less than half the length of the head-shield. Neck-segment strong, marked off by deep furrow. Glabella convex, subcylindrical, about twice as long as wide, and measuring about one-fourth the width and two-thirds the length of the head-shield. At its base is a pair of small nodular basal lobes, in most specimens quite inconspicuous. Two large tubercles are situated in a line down the middle of the glabella, followed by a similar median one on the occipital segment. Occipital segment strong, rounded, separated off by deep furrow. On cheeks at anterior end of glabella is a pair of large tubercles, one on each side.



1 2

Brachymetopus Strzeleckii, McCoy.

Fig. 1, the head-shield, and Fig. 2, the pygidium (restored). Restorations founded on the type-specimens. Enlarged about 8 times natural size. Carboniferous Limestone : New South Wales.

No facial sutures visible. Eyes prominent, reniform, less than half the length of the glabella, distant from axial furrows about one-third the width of the cheeks, and about their own length from posterior margin. Surface of head-shield, including glabella, border, and neck-segment, rather coarsely tuberculated. An indistinct ring of larger tubercles surrounds eyes, and a large tubercle is situated at each end of eyes on inner side. Thorax unknown. Pygidium semicircular, slightly convex, with spinose margin. Axis broad, conical, about one-third the width of pygidium at front end ; tapers rather rapidly to obtuse point, nearly touching border ; consists of 9–10 segments, of which eight rings are distinct and completely tuberculated across ; the 1st, 3rd, 5th, and 7th rings have in addition a large median tubercle. Lateral lobes composed of six (? seven in some) pairs of pleuræ, of which the last pair is very small ; each pleura is gently curved, and is divided unequally by a strong longitudinal furrow into a broader, raised, rounded, posterior ridge and a narrower, anterior ridge. The posterior ridge of each pleura crosses a distinct raised, rounded border which surrounds the pygidium and bears a large tubercle at the spot where it crosses and a single median one behind the axis. The posterior pleural ridges are prolonged into short, recurved, equidistant, and subequal spines, projecting freely beyond the margin. (In one specimen there

seems to be a median spine behind the axis. In another immature example the anterior two or three pairs of spines are half as long as the whole pygidium.) Surface of pygidium rather coarsely tuberculated; the posterior ridge of each pleura bears 4–5 tubercles, and the anterior ridge 5–6 smaller ones. The axial rings bear each 5–7 tubercles.

DIMENSIONS.

	mm.
Length of head-shield	3·0
Width of head-shield	4·5
Length of pygidium	2·5
Width of pygidium	4·0

REMARKS.—De Koninck[1] published a fuller description of this species than McCoy, but the figures differ in some respects from those given by the latter and from the type-specimens, though the differences are only of minor importance. As stated in the text by De Koninck and indicated in the figure, the lateral lobes of the pygidium possess seven pairs of pleuræ, but the last pair is very small and short; the margin also possesses seven pairs of spines, but no median one behind the axis. In McCoy's figure there are eight pairs of spines and no median one. De Koninck states that the axis of the pygidium consists of 17 segments, but his figure only shows 7, while that of McCoy shows 10. In De Koninck's figure of the head-shield the genal angles are produced backwards and pointed, instead of being nearly rectangular and provided with spines; the glabella, also, is made broad and subtriangular, instead of narrow and subcylindrical as in the types; and the basal furrows or lobes are neither mentioned in the description nor indicated in the figures.

AFFINITIES.—McCoy remarks (op. cit.) that "the greater size of the glabella and its being widest at the base will distinguish the head from that of *Phillipsia* [*Brachymetopus*] *Maccoyi* (Portk.), and the granulation extending entirely across the segments and the spinose margin will distinguish the pygidium from that of *P.* [*Br.*] *discors* (McCoy)." It may, however, be mentioned that the number of segments in the pygidial axis of the latter is much greater, being 17. McCoy also says that *Br. Maccoyi* "is at first sight difficult to distinguish specifically from the Australian species," but the pygidium of the former has 15 segments in the axis, and no spines on the margin, as well as no distinct border with regularly arranged tubercles. In the other British species there are likewise no marginal spines nor border, and all have a greater number of pygidial segments, *Br. ouralicus* having 17 and *Br. hibernicus* 11.

McCoy gave as generic characters the circle of tubercles round the eyes and the pair of large tubercles at the front end of the glabella, but these may well be considered of lower classificatory value, and likewise the relatively greater length of the glabella as compared with European species. It does not, however, seem possible to regard the peculiar pygidial characters in quite the same light, though, as Vogdes[2] says, we have many other genera of

[1] Foss. Palæoz. Nouv. Galles, 1877, p. 352, pl. xxiv, figs. 10*a*, *b*, *c*.
[2] Vogdes: Trans. Acad. Sc. St. Louis, vol. v (1892), p. 617.

trilobites with spinose and non-spinose representatives. The fewer number of segments in the pygidium and the raised spinigerous border separate it from all the European forms. The genus or subgenus *Phaetonides*, as now understood, is partly distinguished for analogous reasons from the typical *Proetus*; and it seems open to question whether the European species of *Brachymetopus* should not be regarded as constituting a distinct group or subgenus, for which the name *Brachymetopina* may be suggested. Oehlert,[1] in his review of the genus *Brachymetopus* and its allies, does not mention any species with a spinigerous margin to the pygidium; and Claypole [2] was convinced that with the single possible exception of *Phillipsia lodiensis*, Meek, and *Dalmanites* (?) *Cuyahogæ*, Claypole (see below), every Carboniferous trilobite on either side of the Atlantic possessed a pygidium with a definite even outline. Von Möller [3] compared the Australian species *Br. Strzeleckii* with Russian forms, but in his description ascribes to it too many pygidial segments. It is worthy of remark that he figures (op. cit., t. ii, fig. 32) a head-shield (doubtfully attributed to *Br. ouralicus*) which shows the circle of tubercles round the eyes, the pair of large tubercles in front of the glabella, and one median tubercle on the glabella, which are features well marked in *Br. Strzeleckii*.

It is, however, specially interesting to find in the Waverly Group (Carboniferous) of North America members of the genus *Brachymetopus* with spinigerous pygidia like the Australian species. Such are *Br. lodiensis*, Meek,[4] from the Cuyahoga Shales of Ohio, of which Herrick [5] expresses a doubt whether it is a true *Brachymetopus*; *Br. spinosus*, Herrick,[6] and probably *Br. immaturus*, Herrick,[7] and *Br. occidentalis*,[8] Herrick, the three latter of which were referred by Herrick to the genus *Phaetonides*.[9] There is also *Br. armatus*, Vogdes,[10] from the Waverly of Missouri, with a single pair of spines, and *Br. Cuyahogæ*, Claypole, which according to Vogdes (op. cit.) is only an imperfectly preserved example of *Brachymetopus*, and not one of the Phacopidæ.

As McCoy's figures of *Br. Strzeleckii* are not very clear, and Plews' [11] figure is misleading, a restoration, based on the types, is here given of the head-shield and pygidium. (Figs. 1, 2, p. 194.)

The species has been recorded by Etheridge, jun. (Cat. Austr. Foss., Camb. 1878, p. 41), from Dunvegan, Burragood, and Glen William, all in New South Wales.

[1] Oehlert: Bull. Soc. Et. Scient. Angers, 1885, p. 10 (extract).
[2] Mon. Brit. Carb. Trilob. (Palæont. Soc., 1884), p. 77.
[3] Von Möller: Bull. Soc. Imp. Nat. Moscou, xl (1867), p. 145.
[4] Rep. Geol. Surv. Ohio, vol. ii, Geol. and Palæont., 1875, p. 323, pl. xviii, fig. 3 [*Phillipsia* (*Griffithides?*) *lodiensis*, Meek].
[5] Herrick: Bull. Denison Univ., vol. ii, pt. 1 (1887), p. 57.
[6] Ibid., vol. iv (1889), p. 58, pl. i, figs. 4, 5; and Bull. Geol. Soc. Amer., vol. ii (1891), p. 42, pl. i, fig. 13.
[7] Ibid., vol. iv (1889), p. 59, pl. i, figs. 9–15.
[8] Ibid., p. 57, pl. i, figs. 10*a*, *b*.
[9] Vogdes: Bibliogr. Palæoz. Crust. (Occas. Papers Calif. Acad. Sc.), 1893, p. 284.
[10] Vogdes: Trans. St. Louis Acad. Sc., vol. v (1892), p. 617, pl. xv, figs. 4, 5.
[11] Plews: Trans. N. Engl. Instit. Min. Engin., vol. vi, p. 34, pl. iv.

II.—Creechbarrow in Purbeck.—No. 2 (*continued*).

By W. H. Hudleston, M.A., F.R.S., F.G.S.

(PLATE XI.)

(*Concluded from the April Number, p.* 154.)

Varieties of the Creechbarrow Limestone.—There are considerable extremes in this respect, ranging from a soft marly deposit, which soils the fingers like whitening, to a hard compact rock, which takes a good polish. Unquestionably the most dense and compact limestone is that near the summit, whilst the soft marly beds are on the northern slope, and especially near the 500 feet contour, where some of them are earthy and contain a considerable amount of impurity, so that they may at least be called marly limestones. On the other hand, there are compact white limestones, where nests of dog-tooth spar form no inconsiderable portion of the mass. Quartz grains may be noted on most of the weathered surfaces.

The more compact and denser limestones, which prevail near the summit, may be roughly divided into non-pisolitic and pisolitic rocks. Thus, for instance, I have before me (Group 1) specimens of a very heavy and partially calcitic rock. It is a hard whitish limestone without pisolites, but largely interspersed with buff-coloured patches, not unlike some dolomites. Calcitic nests and strings occur, and also strings and stars of black oxide of manganese: the external surface is rough and somewhat honeycombed, and full of curious impressions, some of which may have had an organic origin.

Group 2 comprises those specimens where the pisolitic character is indicated, but not very obviously. A characteristic specimen may be described as follows:—A large fragment of a creamy white tufaceous limestone, with specks and threads of black oxide of manganese in places: flattened pisolitic bodies in brownish calcite are numerous, but not very distinct. There are casts of interiors of a univalve shell, which is most probably *Paludina*. The whole of this fragment has a tufaceous aspect, and is free from buff-coloured patches. The external surface is rough, and in one corner is full of curious shapes, which are doubtless concretionary bodies developed by weathering. On further examination of these curious shapes, I note indications of the concentric structure which convinces me that they are pisolites developed by weathering.

The Pisolites.[1] (Group 3.)—Originally I divided these limestones into four groups, but the pisolitic limestones may be taken as one group. The following is the description of a specimen of this class of rock.

A creamy tufaceous limestone with some buff-coloured patches and with specks and threads of manganese oxide. Sections of ordinary pisolites here and there. But this specimen is remarkable for three very large *horseshoe sections*, which certainly represent concretions in brown calcite. The first specimens I obtained were incomplete

[1] The accompanying Plate is intended to illustrate concretionary or pisolitic action as well as to serve the palæontology of the limestone.

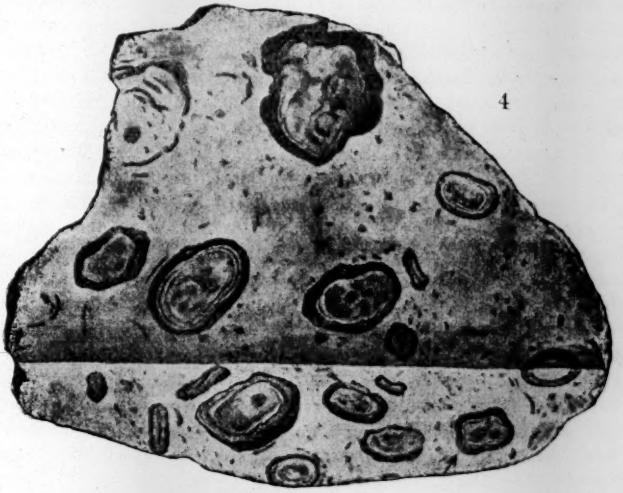
in outline, thus causing an appearance of being open at one end, like a horseshoe. Specimens subsequently obtained showed that this was not exactly the case. Where the periphery of the section is complete, as in the specimen figured on Plate XI, Figs. 2 and 3, it is seen that the section of this large concretionary body is thick at one end and thin at the other. Fig. 3 of the Plate especially shows a side view of this curious body, where, taken by itself alone, it might almost be regarded as a fragment of a big belemnite. The section shows a series of concentric rings of brown calcite with a large hollow in the centre filled with the ordinary matrix. There is no radial structure; one end of the circle, as previously noted, is thick, whilst the opposite end thins out to such an extent that in some specimens it is not to be traced. Some of these 'horseshoe' sections are nearly $1\frac{1}{2}$ inches in diameter.

The Egg-like Body. (Plate XI, Fig. 4.)—For a long time these so-called horseshoe concretions were a puzzle to me, and as they were for the most part only obtained in fragments, there seemed to be no possibility of solving the enigma. At last, by good luck we stumbled on a still more curious body, which is perhaps the most perfect pisolite ever discovered. In this case we perceive a pisolitic concretion with an interior like a very small egg, of which the shell, represented by the concentric layers of brown calcite, is developed so obliquely that it is quite thick on one side and thin on the other side. This specimen has been broken so fortunately that we recognize our horseshoe section at once, with the matrix in the form of an egg projecting from the unequally developed circle.

Those who regard pisolites as organic will doubtless welcome this egg-like form as a new species. But, as a further illustration of the eccentricities of concretionary action, I would direct attention to Fig. 1 of Plate XI, where the shell of a univalve, most probably a *Melanopsis*, has been encysted in a number of concentric layers of brown calcite. A similar concretionary action has taken place round other specimens of univalve shells, of which sections are given in Figs. 6 and 8 of the same Plate. This action is interesting from a lithological point of view, but, as we shall perceive subsequently, it renders the palæontology more difficult of interpretation. However, the above instances serve to show that concretionary action has been rampant in the Creechbarrow Limestone, and it is to this action that we must ascribe most of the peculiarities of the rock.

In those cases where the pisolitic concretions are numerous and the limestone is very compact, as shown in Fig. 4, the rock cuts well and takes a fairly good polish. In this instance the ground-mass is of a dull cream colour, mottled with buff patches, and the sections of the pisolites appear in dark brown calcite, which contrasts well with the non-crystallized matrix. There is much more variety in the shapes of the pisolites than can be gathered from the small fragment figured, but they may be classed as quadrate, circular, and oblong, some showing considerable irregularity of outline. Whatever may be the shape of these smaller concretionary bodies, they conform to the conditions already detailed with regard

to the larger ones previously described as the horseshoe form. The structure is entirely concentric, and this is shown in the flattened pisolites as well as in the circular ones. Some of these bodies are seen to be compound, with a very irregular periphery, having two or more foci of crystallization, and in this way very curious figures result.



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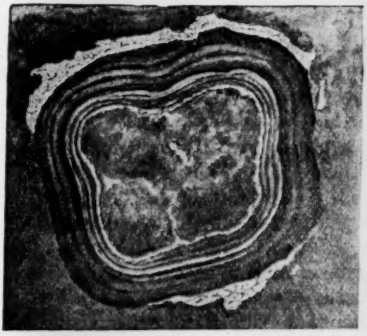


4*a*

Fig. 4.—Fragment of the hard pisolitic limestone showing two faces cut at right angles to each other and polished. × 1½.

Fig. 4*a*.—Section of one of the pisolites, drawn as a transparency. × 6.

The magnified section of one of the quadrate pisolites (Fig. 4*a*) displays some features which are not seen in all the specimens. For instance, there are two lacunæ of clear calcite, which partly separate the regular annular system of brown calcite from the ordinary matrix. This is probably due to partial solution of the matrix subsequent to the formation of the pisolitic concretion We

notice belts of clear calcite also in the annular system, especially towards the interior, giving the rings an agate-like appearance. The core, or centre of the pisolite, consists of the matrix partially modified, but without the brown specks which characterize it. This appears to be the case in all sections of the pisolites which I have examined, and suggests that the slight amount of colouring matter, due to iron oxide, which characterizes the rings of brown calcite, has been transferred from the included portion of the matrix to the annular system surrounding it by a sort of centrifugal flow-action, such as that which forms the ironstone shells of limonitic deposits. In the case of some of the pisolites the centre consists of clear crystalline calcite, making the analogy with the ordinary siliceous agate still more complete.

There remains only one further remark to make in dealing with these curious pisolites, and that refers to a suggestion that these concretionary bodies may possibly in the first instance have been due to Nummulites. Everything tends to refute this supposition, more especially the association of these pisolitic limestones with *Paludina* and *Melanopsis*. Yet it must be admitted that there is a considerable resemblance to limestones showing sections of Nummulites, although the resemblance is apparent rather than real, as may be seen on closer investigation, and it can be safely affirmed that nothing approaching organic structure has hitherto been detected in these pisolites. It is certainly a curious coincidence that both *Nummulites lævigatus* and *N. elegans* occur in the Lower Eocenes of this country, mainly perhaps in the Brackleshams, but also in the Barton Beds; so that, if the Creechbarrow Limestone had been of marine origin, there would have been nothing surprising in the occurrence of Nummulites in any beds of Bagshot or of approximate age.[1]

Palæontology.—Very little can be said under this head, as the only specimens of fossils from the Limestone have been derived from the limited area of the summit pit or the immediate neighbourhood. There can be no doubt that *Paludina* is fairly common, as it occurs both in the form of shells and casts by no means infrequently. The shells are often obscured by a concretionary investment, as previously stated, but there is sufficient material to form a fair idea of the species. It is a form which clearly differs from the ordinary Purbeck species (*P. carinifera* and *P. elongata*), but which has a fairly good resemblance to the Bembridge species, *Paludina lenta*, Solander.[2]

[1] According to Professor Rupert Jones, writing of the physical features of the Bagshot district in 1880 (Proc. Geol. Assoc., vol. vi, p. 437), "the Bagshot sands are the shallow water and western equivalents of the great Nummulitic formation, which is represented in the east by the thick Nummulite limestones, deposited in the open ocean of the period."

[2] In my paper in the Geological Magazine (1902, p. 251), I referred this form to *P. media*, Woodw., a synonym of *P. lenta*, Solander, the latter being the correct name. The history of *P. lenta* is rather a singular one. It was first described by Solander (1766) in Brander's Foss. Hants, and is regarded as ranging from the Woolwich (and Reading) Beds to the Hempstead, Bembridge, and Headon Beds. Hence it is essentially an Eocene and Oligocene species.

No object would be gained by attempting a technical description of fossils so obscured by incrustation as are these Creechbarrow Gasteropoda, but I must direct the attention of the reader to the accompanying Plate XI. According to my ideas, Figs. 1 and 5 represent the back and front view respectively of a form which may possibly be a member of the Melaniadæ. The shell shown in Fig. 1 is enclosed in a series of cysts; the one shown in Fig. 5 appears to me to represent the same species. It is true that the aperture, in its present condition, gives us very little insight into the true character of the shell, but this is due to disfiguration from several causes. Fig. 6 may represent a section of the same species, and here again the elongate character of the whorls points to some member of the Melaniadæ rather than to *Paludina*.

In the case of Fig. 9 the aperture has been better preserved, and few would doubt that this specimen represents a *Paludina*. It most resembles *P. concinna*, Sowerby, which Mr. Bullen Newton ("British Oligocene and Eocene Mollusca") regards as the same as *P. lenta*. Although there are plenty of casts in the limestone which one would refer without hesitation to *Paludina*, this is the only specimen of a shell which shows the *Paludina* mouth with certainty.

Figs. 7 and 8 of the Plate represent specimens (the latter in section) which have suffered terribly from incrustation, to the complete obliteration of the true external form; yet I think that in them we may recognize *Melanopsis brevis*, Sowerby, described from the Bembridge series. I have no doubt that a more extended search would yield a larger series of fossils, since the few specimens of Gasteropoda which have been figured were derived from a very limited area, viz. the summit pit.

As regards any other fossils from the Creechbarrow Beds, there is a fragment something like *Ditrupa* in one of the more earthy limestones. A bivalve not unlike a *Lucina* was also obtained from a fragment of an ironstone grit found on the surface between the summit and the eastern spur, but, as I have never seen this particular bed *in sitû*, too much importance should not be attached to this 'find.'

Conclusion.—The question of the actual age of the Creechbarrow Limestone is one which I have naturally deferred to the last, in order that we might be in possession of all the available evidence. Its approximate age is clear enough as being Lower Tertiary, but the question now more particularly to be solved is this—Are we to believe that the Creechbarrow Limestone is really of Lower Bagshot age and rather low down in the Bagshot series, as appearances might seem to indicate, or are we to believe that it is of Oligocene age and a local representative of the Bembridge Limestone? It has already been admitted that hitherto I have failed to settle this question from a study of the stratigraphy of the hill, although the bulging of the Pipeclay series is certainly in favour of the view that the Creechbarrow Beds do not overlie the Pipeclay series, as must be the case if they or any portion of them represent the Bembridge Limestone.

Do we obtain a better clue either from the lithology or the palæontology of the limestone? I fear not. The two species of Gasteropoda, which may be regarded as fairly well identified, viz. *Paludina lenta* and *Melanopsis brevis*, are certainly Bembridge species, but the former occurs in the Woolwich Beds, and we may well believe that the latter also had a long life as a Lower Tertiary fresh-water species, so that its presence must not be taken as indicative of any special horizon. The lithology is equally uncertain.

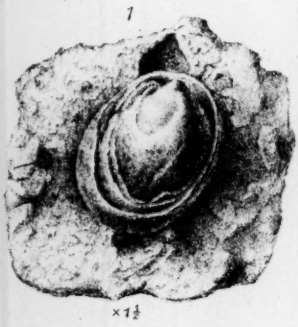
So far as I am acquainted with museum specimens of the Bembridge Limestone, it has a somewhat different aspect to that from near the summit of Creechbarrow, and is, on the whole, non-pisolitic. Yet there are in the Bembridge Limestone some very enigmatical bodies. Amongst these are the supposed 'Cocoons' referred to by the late Mr. F. E. Edwards as possibly being the eggs of fresh-water tortoises, or even snails. These bodies are said to possess no internal structure. Not having any of these 'Cocoons' by me at the present moment, I am unable to give any further description of them, although I strongly suspect that they are not organic any more than our 'horseshoe' pisolites, but most probably the result of concretionary action. Hence there would seem to be established a certain degree of analogy, *quâ* lithology, between the Bembridge and Creechbarrow Limestones, although this can scarcely be allowed to outweigh the stratigraphical inferences to be drawn from the bulging of the Pipeclay series.

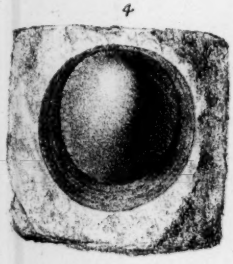
Thus, on summing up all the evidence hitherto available, I rather incline to the view that the Creechbarrow Limestone and associated beds are of Lower Bagshot age, yet at the same time I am bound to admit that it is a point which can only be decided with certainty by further investigation.

Postscript.—Since the article on Creechbarrow was completed there are two points on which a certain amount of additional information has been received.

(1) A deep boring south of Mr. Bond's brickyard is thought by Mr. Leonard Pike to indicate the presence of Pipeclay at a considerable depth within the area hitherto regarded as sterile. If the clays in this boring represent the great mass of Pipeclay such as has been excavated from the 'Old Clay Pits,' then the theory that Creechbarrow bulges the Pipeclay series can scarcely be maintained any longer. But if, on the other hand, the material lately discovered is merely a local manifestation of Pipeclay such as might occur to a small extent on almost any Bagshot horizon, the recent discovery cannot be regarded as contravening the general impression which has hitherto prevailed.

(2) On referring to Edwards' monograph of the Eocene Mollusca (Pal. Soc., 1852), I perceive that he describes with considerable detail the bodies regarded as the casts of eggs which were found in the Bembridge Limestone. Those most commonly found, he says, present a close resemblance both in size and shape to the eggs of several of the fresh-water tortoises, and may be casts of the eggs of





G. West lith.

SHELLS & CONCRETIONS FROM
THE CREECHBARROW LIMESTONE.

species of *Trionyx* or *Emys*, which lived in the Eocene marshes. Others he thought might be casts of some Helicidæ.

Although we cannot show anything from the Creechbarrow Limestone which exactly corresponds to the supposed eggs from the Bembridge Limestone, yet a successful reconstruction of the larger 'horseshoe' pisolites from Creechbarrow might possibly produce forms not unlike the 'eggs' which attracted the attention of Mr. Edwards. If this should prove to be the case, there may be more similarity between the two limestones than has hitherto been supposed.

EXPLANATION OF PLATE XI.

FIG. 1.—Gasteropod encysted in concretionary layers; ? one of the Melaniadæ. × 1½.
,, 2.—Section, approximately horizontal, of the 'horseshoe' concretion. Nat. size.
,, 3.—Section of the 'horseshoe' concretion, drawn so as to show a portion of the outer wall. Nat. size.
,, 4.—Egg-like body inside the 'horseshoe' concretion. × 3.
,, 5.—Gasteropod; ? one of the Melaniadæ. Front aspect. × 1½.
,, 6.—Vertical section of Gasteropod, probably the same species as shown in Figs. 1 and 5. × 1½.
,, 7.—Cf. *Melanopsis brevis*, Sowerby. Front aspect. × 1½.
,, 8.—Section of a similar specimen. × 1½.
,, 9.—*Paludina* cf. *lenta*, Solander. Front aspect. × 1½.

N.B.—Figs. 6 and 8 show the encrusting action to which most of these shells have been subjected, and which tends to obscure their true character.

III.—The Lower Pliocene Bone-bed of Concud, Province of Teruel, Spain.

By Arthur Smith Woodward, LL.D., F.R.S., of the British Museum.

(PLATE XII.)

FROM time immemorial a remarkable accumulation of bones in the province of Teruel, Spain, has attracted attention. It is especially conspicuous in the low range of hills near Concud, and the people of that village seem to have generally regarded it as marking an ancient battlefield. So long ago as 1754 Torrubia briefly described this deposit in his Spanish Natural History;[1] but his curiosity seems to have been aroused not so much by the bones themselves as by the crystalline calcite found occupying many of their cavities. Twenty years later an Englishman, William Bowles, again referred[2] to the same bone-bed, and described it as containing the remains of men and women mingled with the bones of horses, donkeys, oxen, and smaller domestic animals. He also observed that the limestone above the bone-bed was filled with land and fresh-water shells. Cuvier quoted Bowles' description in his treatise on fossil bones,[3] and after an examination of some teeth and bone-fragments collected by Proust at Concud, he was inclined to believe that these fossils really represented domestic animals as already determined, though he found

[1] J. Torrubia: "Aparato para la Historia Natural Española" (1754); German edition (1773), p. 63.

[2] Guill. Bowles: "Introduccion a la Historia Natural y a la Geografia Física de España" (1775), p. 210.

[3] G. Cuvier: "Recherches sur les Ossemens Fossiles," 4th ed. (1835), vol. vi, p. 427.

no associated evidence of man. He suspected that Bowles was wrong in describing the bone-bed as a regular stratum, and thought it would probably prove to be a breccia introduced into a fissure in comparatively modern times.

The true nature and age of the deposit at Concud were first determined by the researches of De Verneuil, Collomb, and De Lorière,[1] who not only made geological observations but also collected fossils and submitted them to Paul Gervais. In 1853 Gervais perceived that the supposed teeth of horses and donkeys belonged to the extinct *Hipparion*;[2] and it became evident that the basin of Teruel was occupied by an Upper Tertiary lake deposit, closely resembling other lacustrine formations which were then being recognised in various parts both of Spain and France. Ten years later the province of Teruel was systematically surveyed by Vilanova, who published a pioneer geological map and description;[3] while in 1885 the province was the subject of a final memoir by Cortázar, issued by the present Geological Survey of Spain.[4] All these researches gradually confirmed the impression that the Concud bone-bed contained the remains of the same Lower Pliocene mammalian fauna as the well-known deposits of Mt. Léberon, in France, and Pikermi, in Greece.[5]

The remote and elevated plain on which Teruel is situated was made readily accessible last year by the opening of the Aragon Railway from Sagunto to Calatayud. Being interested in the Pikermi fauna, I therefore decided in the Autumn to spend a brief holiday at Concud and make a preliminary inspection of the ground. Thanks to the kind intervention of A. Frederick Ivens, Esq., British Vice-Consul in Valencia, and E. Harker, Esq., British Vice-Consul in Castellon, I obtained introductions to Señor Don Gregorio Lleo, Chief of the Forest Department in Teruel, to the Provincial Governor, and to the Alcalde of Concud. The friendly reception and help accorded to me by these officers and by the village council of Concud enabled me to attain my object; and among the villagers themselves I found both willing guides and workmen. I am also much indebted to Mr. Thomas Rees, of the Grao de Valencia, who accompanied myself and my wife, and contributed to our success by his intimate knowledge of the Spaniards and their customs.

Concud is about three miles distant from Teruel in a northerly direction, and the low hills in which the bone-bed is exposed are nearly two miles further away. These hills are at an elevation of

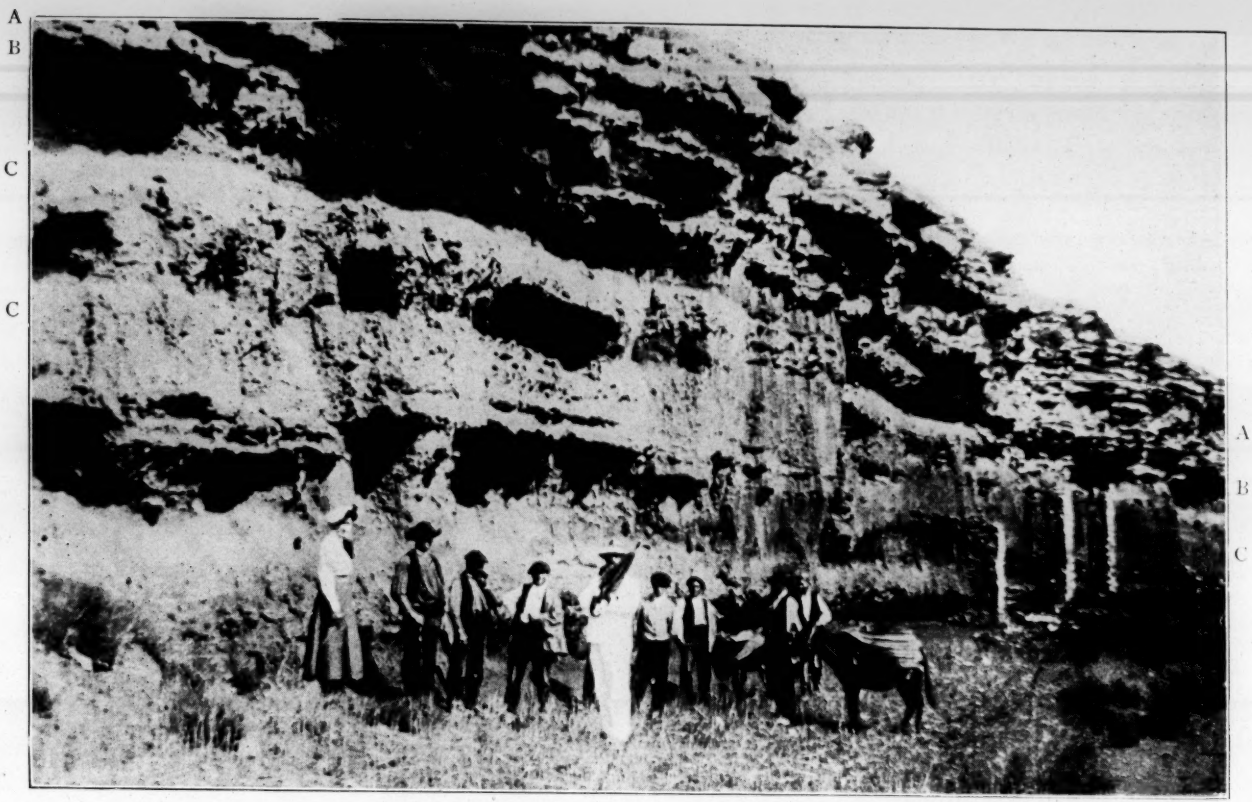
[1] E. P. de Verneuil & E. Collomb, "Coup d'Œil sur la Constitution Géologique de quelques Provinces de l'Espagne": Bull. Soc. Géol. France [2], vol. x (1853), p. 74.—P. Gervais, "Description des Ossements Fossiles de Mammifères rapportés d'Espagne par MM. de Verneuil, Collomb, et de Lorière": ibid., pp. 147–167, pls. iv–vi.

[2] P. Gervais: loc. cit., p. 155, pl. iv, fig. 4.

[3] J. Vilanova y Piera: "Ensayo de Descripcion Geognóstica de la Provincia de Teruel": Junta General de Estadística, 1863.

[4] D. de Cortázar, "Bosquejo Físico-Geológico y Minero de la Provincia de Teruel": Bol. Com. Mapa Geol. de España, vol. xii (1885), pp. 263–607, with map and sections.

[5] A. Gaudry: "Animaux Fossiles et Géologie de l'Attique," 1862.



Barranca de las Calaveras, Concud, Spain.

(Explored by Dr. Arthur Smith Woodward, September, 1902.)

about 3,000 feet above the level of the sea, and capped with irregular thin beds of limestone. They are so barren as to be scarcely of use even for the pasturage of sheep, of which poor flocks are kept. At the time of our visit the red-legged partridge was in season and very abundant.

For a distance of about four miles along the outcrop we continually found traces of bones and teeth in the talus from the softer beds immediately beneath the limestones; but the bone-bed itself was best exposed in the vertical walls of the classical ravine—the Barranca de las Calaveras, or Valley of Skulls—originally described by Torrubia and Bowles. We eventually halted here and spent a few days in extricating the fossils.

The northern wall at the entrance of this small ravine is shown in the photograph reproduced in Plate XII. At the top (A) are observed the overhanging ledges of limestone. Beneath these is a layer of comparatively soft marl and sand (B) which is filled at most spots with bones. The lower half of the section then consists of hard red marl and sandy layers (C), with occasional beds of well-rounded pebbles, which form prominent ridges on the weathered face. At this point the bone-bed is inconveniently situated for satisfactory excavation. We therefore followed it to the head of the ravine, where the floor rises to its level and makes it comparatively accessible.

At the point where our chief excavation was made, the overhanging beds of limestone are from 4 to 6 metres in thickness. They form irregular layers, some consisting chiefly of the fresh-water shells described by Vilanova, others composed entirely of chemically precipitated travertine. The shelly layers contain an occasional bone or tooth, but no accumulation of mammalian remains. At the base of the limestone there are traces of lignite and bituminous marl, also enclosing a few scattered bones and teeth. Next below is a bed of white marl, about one metre in thickness, almost unfossiliferous but with occasional traces of lignite. Then follows a greenish-yellow, soft, sandy bed, about 30 centimetres thick, with an admixture of white and greenish marl, sometimes bituminous at the base. This is the true bone-bed, and immediately below it occurs the unfossiliferous series of brick-red sandy marls and conglomerates so well shown in Plate XII (C).

The bones in the bone-bed do not form an absolutely continuous mass, but occur rather in dense patches. They vary in state of preservation, and at the spot where we worked they were made fragile by moisture and much distorted by crushing. The specimens we obtained, indeed, suggest that they had become more or less rotten even before burial; and I observed no satisfactory evidence of naturally associated bones—either pieces of limbs or of vertebral column—such as are common in the bone-beds of Pikermi. The teeth alone proved to be well preserved, and complete jaws were often met with. There were no associated pebbles.

The large majority of the remains in the Concud bone-bed belong to *Hipparion gracilis*. The teeth of this species are especially common everywhere. There is also evidence of a larger variety

of *Hipparion*, which may perhaps belong to a second species. We found one mandible and one upper jaw of *Rhinoceros*, with teeth closely resembling those of *R. Schleiermacheri*, but not quite identical. Some decayed fragments of limb-bones and a small piece of a tooth, not worth preservation, clearly represented *Mastodon*. A mandibular ramus, various teeth, and horn-cores are identifiable with *Gazella brevicornis*. Other teeth represent an undetermined larger antelope. Vilanova has also recorded doubtful traces of *Cervus* and *Hyæna eximia*,[1] while Cortázar mentions the discovery of teeth of *Sus*.[2]

A deposit which yields remains of so interesting a mammalian fauna to the casual work of a few days with a small party of men, deserves further systematic exploration. It is true that in all the spots we examined near Concud excavations are rendered difficult by the mass of overlying limestones, which, in the absence of timber, need to be supported by pillars of masonry when the marl and bone-bed are removed. Similar bones, however, have been noticed in many other parts of the Teruel basin, and it is quite likely that extended search would lead to the discovery of better preserved and more readily accessible material.

Such renewed and extended exploration would also be of much interest from a purely geological point of view, considering the result of recent researches in some of the so-called Tertiary lake basins of western North America, and in the remarkable Tarija Valley in Bolivia. According to Matthew[3] and Hatcher,[4] the North American deposits in question, with their wonderful bone-beds, cannot have been formed in great sheets of water, but are partly wind-borne, partly fluviatile, partly formed in temporary pools. According to Nordenskjöld,[5] the Tarija Valley was once a steppe, and the remains of *Mastodon* and other quadrupeds now found buried there represent animals which lived on the spot and were engulphed in shifting pools and mud-flats. Hatcher, indeed, considers that similar deposits are now accumulating on some of the flood-plains in the higher reaches of the great rivers of South America. Quoting a recent observer, Mr. H. H. Smith, he alludes to a plain about 400 miles long and in some places 150 miles wide, which is periodically flooded by the River Paraguay. "Even at low water at least one-fourth of it is flooded: when the river is at its highest the whole plain is a vast lake covered with floating grass and weeds; it is possible to pass almost straight across it in a canoe, though with great difficulty. Only a few islands remain here and there; jaguars, deer, and other animals take refuge on them."

[1] Named *Hyænictis græca*? by Vilanova, redetermined by Gaudry, "Les Ancêtres de nos Animaux," 1888, p. 202.

[2] D. de Cortázar: loc. cit., p. 449.

[3] W. D. Matthew, "Is the White River Tertiary an Eolian Formation?": Amer. Nat., vol. xxxiii (1899), pp. 403–408.

[4] J. B. Hatcher, "Origin of the Oligocene and Miocene Deposits of the Great Plains": Proc. Amer. Phil. Soc., vol. xli (1902), pp. 113–131.

[5] E. Nordenskjöld, "Ueber die Säugethier-fossilien im Tarijathal, Südamerika": Bull. Geol. Inst. Upsala, vol. v (1901), pp. 261–266.

Under these circumstances some at least of the skeletons of drowned animals would be buried in the sediment at the bottom of the flood; while any accumulation of bones lying on the plain would be rapidly entombed. That great accumulations of this kind often do occur near water, is indicated by Mr. Hesketh Prichard's observations recorded in his recent book on Patagonia.[1] On the bank of one small muddy lake he found a heap of at least 500 skeletons of guanaco, which had perished during the severities of the previous winter. "Their long necks were outstretched, the rime of weather upon their decaying hides, and their bone-joints glistening through the wounds made by the beaks of carrion-birds." A desolate plain adjoining Lake Viedma is also described as covered with the bones of guanaco and other mammals in great profusion. In fact, in winter the animals seem to congregate near drinking-places where the water is likely to be free from ice, and there they die of starvation in immense numbers.

According to an observation communicated to me by Professor McKenny Hughes, when bones are exposed to the vicissitudes of ordinary weathering they often disintegrate into sharp flakes. He has noticed this phenomenon especially in the case of bones of rabbits scattered on the ground. It is therefore quite likely that the sharp splinters found mingled with the complete bones in many of the bone-beds are not the result of any physical violence, but merely of prolonged exposure to the elements.

IV.—The Diffusion of Granite into Crystalline Schists.

By Edward Greenly, F.G.S.

(PLATE XIII.)

1. *Roberts-Austen's Experiments on the Diffusion of Metals.*

ABOUT a year ago my friend Professor Dobbie, of the University College of North Wales, drew my attention to the remarkable experiments of Sir W. Roberts-Austen (whose premature death we must lament as a very great loss to science) on the diffusion of solid metals, suggesting that they might have some geological application. The phenomena referred to in this paper, in which I have been very keenly interested ever since my work as a Geological Surveyor in Eastern Sutherland, occurred to my mind at the time as a probable case; but after some reflection certain difficulties began to appear, and I put the subject aside for a while. The very suggestive address of General McMahon to the Geological Section of the British Association at Belfast has reawakened my interest; and it seems to me worth while to put forward some considerations on the matter, somewhat speculative indeed, but which may perhaps be of service in stimulating research on a fascinating though difficult subject.

Sir W. Roberts-Austen[2] showed that certain selected substances, especially gold and lead, were able to diffuse into each other in the solid state, and at temperatures far below the fusion-point of either.

[1] H. H. Prichard: "Through the Heart of Patagonia" (1902), pp. 189, 203, 254.

[2] Roberts-Austen: Bakerian Lecture, Phil. Trans., 1896, vol. clxxxvii; Proc. Roy. Soc., Oct. 1900, p. 436.

Rods of the metals were placed end to end, and in each case the gold diffused upwards into the lead.

At the end of four years, at only 18° C. (ordinary Summer temperature), gold could be detected 9·95 mm. from the contact. At 251° C., which is still 75° C. below the fusion-point of lead, at the end of 31 days, ·002 per cent. of gold was found 7 cm. from the contact. If the column of lead was kept liquid, the diffusion was much faster. But as much gold would pass up into liquid lead in a day as into solid lead at 18° C. in 1000 years.

It is clear, therefore, that in solids, as General McMahon remarks, as well as in liquids and gases, there is a good deal of molecular movement; and as we cannot suppose this to be confined to a few cases only, we may expect diffusion to take place between many solids under favourable conditions. Any pair of solids cannot, of course, be expected to diffuse, any more than any pair of liquids—mercury and water, for example. But solids with as much in common as most silicate-bearing rocks might reasonably be expected to do so.

2. *The Metamorphic Theory of Igneous Rocks.*

Before attempting to apply Roberts-Austen's results, it will be desirable to refer to the relation of granites to crystalline schists in highly metamorphic regions; and, first of all, to review a theory which at one time had much influence upon geological opinion, and even now continues to recur from time to time to the mind of the worker in regions of this description.

The eruptive nature of granite has, ever since the classic demonstration of Hutton, been rightly regarded as one of the established truths of geology, and this has been confirmed by numberless examples since discovered in all parts of the world, and in rocks of all ages.

But the phenomena to be seen at the margins of granites do not always show clear evidence of intrusion, and the study of some of these led to a modification, about the middle of the nineteenth century, of Hutton's original view. That granites are often, perhaps generally, intrusive, was never, I believe, denied. But it was asserted that in many cases the margins showed a gradual transition into the material of the surrounding rocks; and it was inferred that these rocks had been in such cases, not merely altered in mineral character, but actually melted down, and had recrystallized in cooling as granitoid material; that, in fact, the granite was, in part at any rate, of metamorphic origin. From this view it was an easy transition to that according to which such granites were regarded as of metamorphic origin throughout their whole body; the heat to which such fusion was due being then ascribed, not to intrusion of heated foreign matter, but to local intensification of the internal heat of the earth. A comprehensive resumé of the theory is given, with his usual admirable lucidity, by the late Professor A. H. Green in his "Physical Geology" (ed. 1882, pp. 399-455).

Unfortunately, however, the theory was not always applied in this moderate and scientific spirit. The chemical composition of

even the acid igneous rocks always presented difficulties, but basic rocks and, I believe, even peridotites and serpentines were sometimes supposed to have originated in this way, as well as felsites, which could not have consolidated under plutonic conditions.

It is easy to be wise after the event, and for one period of human thought to point the finger of scorn at the aberrations of its predecessors; and we must not forget that at that time hardly anything was known of the microscopic structure of rocks, and very little more of their chemical composition.[1] When, therefore, in the light of microscopic and chemical research the field evidence for many of the alleged cases of transition broke down, it is not surprising that the whole theory was cast aside, often with no little scorn, and relegated to the limbo of exploded hypotheses.

The remark has been made by Mr. Herbert Spencer that as there is "a soul of goodness in things evil," so often is there, and that very generally, "a soul of truth in things erroneous." And in this old theory there *was* a soul of truth.

It is noteworthy that most of the cases in which the evidence so hopelessly broke down were those where the igneous rocks were surrounded by tracts of ordinary sedimentary rocks that were only locally, not regionally, metamorphosed. Regionally metamorphosed rocks had been, indeed, examined, and speculation aroused concerning them; but the time for systematic research into their phenomena had not yet come.

The past twenty years or so, however, have seen much energetic and enthusiastic research into the crystalline schists, and really scientific methods applied to their problems. Now, during that period descriptions have been given, from time to time, of a good many cases where granitoid rocks which occur in districts of regional metamorphism have been really observed to pass into the surrounding gneissose rocks by perfectly gradual transitions. North America, Scandinavia, Saxony, the Alps, more than one part of the Scottish Highlands, Ireland, and even Anglesey, have furnished examples.[2]

[1] The time and labour demanded by analyses of silicates have always stood in the way of a really thorough knowledge of the chemistry of rocks, and at the present time hardly any work is so much needed in geology, if intelligently directed in conjunction with microscopic and especially with field work.

[2] Lawson: Geol. Rainy Lake Region, 1888, pp. 118, 130, 137.
Van Hise: Pre-Camb. Rocks N. America, Corr. Papers, 1892, p. 488; and, quoting Jukes, Hitchcock, and others, p. 479.
Reusch: The Bömmel and Karm Islands, 1888.
Lehmann: Enst. Altkryst. Sch., pp. 64, 67, etc.
Lory: Etudes Sch. Cryst.: Congrès Inter. Geol., 1888.
Bonney: Pres. Address Geol. Soc., 1886, p. 51, etc.; Two Traverses Cryst. Sch. Alps, Q.J.G.S., 1889, pp. 95, etc.
Barrow: An Intrusion Muscovite-Biotite Gneiss, etc.: Q.J.G.S., 1893, pp. 341, 343, 353.
Horne & Greenly: Fol. Granites and Cryst. Sch. East Sutherland: Q.J.G.S., 1896.
Cole: Metam. Rocks Tyrone and Donegal: Roy. Irish Ac., xxxi (1900).
Greenly: Sillim. Gneiss, Anglesey: Geol. Mag., 1896, p. 495.
Teall: Pres. Address Geol. Soc., 1902, p. lxxiv.
(These references are of course not exhaustive.)

3. *Gneisses and Granites of Eastern Sutherland.*

The phenomena of Eastern Sutherland were described some years ago in a joint paper by Dr. John Horne and myself.[1] The granites, which are generally foliated, lie as sills in a region entirely composed of gneissose rocks in which no original structures whatever have been detected. On parts of the northern coastline, where granulitic, somewhat siliceous rocks prevail, the granitoid matter is injected "lit par lit," producing complex synthetic banded gneisses. But on other parts of the coast, and inland about Kinbrace, where a flaky or wavy biotite gneiss is the dominant type, we find the permeation phenomena.

In "lit par lit" injection the injecting and the injected rock retain their separate individualities, however thin and frequent may be the sills; whereas at the permeation junctions "the margins of a sill fade off into the gneiss through a series of thinner and thinner lenticles" (Pl. XIII, Fig. 1), "the ends of a sill also fading off into the gneiss by a dovetailing of biotitic folia into the granite" (Pl. XIII, Fig. 2). "Finally, large masses occur in which these relations are carried to such a degree of intimacy as to render it very difficult to decide whether to regard them as granite or as gneiss (Pl. XIII, Fig. 3), difficult even to produce a consistent map, all lines being wholly arbitrary" (op. cit., p. 644).[2]

In the same paper (pp. 642–3) evidence is adduced to show that much of the gneissose rock so permeated must be of sedimentary origin. That it does not consist merely of the material of the adjacent granites altered by marginal shearing is shown by the existence of uninjured intrusive junctions at other parts of the same sill (ibid., figs. 2, 3). In conclusion (ibid., pp. 647–8) it was suggested, though with the caution due to the chemical difficulties to be encountered, that the granites might not be wholly foreign matter; and this was alluded to in the discussion by several speakers, who pointed out that the suggestion was really a revival of the older theory which I have described above.

4. *Application of Roberts-Austen's Results.*

Now, in the interpretation of phenomena of this kind the results of Sir W. Roberts-Austen's experiments seem to open up a prospect of considerable help. In the permeation zones of these granites, whatever may be their cause, we see, at any rate, an unquestionable case of the diffusion of one rock into another.

Roberts-Austen has shown (1) that diffusion takes place between closely adpressed solids at ordinary temperature, (2) that with rise

[1] "On Foliated Granites and their relations to the Crystalline Schists in Eastern Sutherland": Q.J.G.S., 1896. The views of our colleague, the late Hugh Miller, jun., are also given in this paper.

[2] I had not at the time this was written read this passage from Lehmann (Enst. Altkryst. Sch., p. 64): "Die Abgrenzung zwischen dem, was als Granit oder Granitgneiss und dem, was als Gneissglimmerschiefer zu bezeichnen wäre, wird oft unmöglich *und kommt ganz auf subjectives Ermessen hinaus*, so schnell wechselt der Gesammtcharakter," but cannot refrain from quoting it now. I put one phrase in italics.

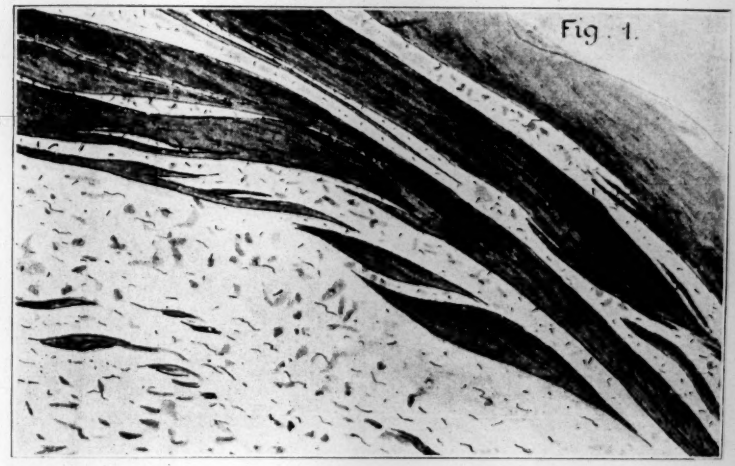


FIG. 1.—Side of Granite Sill, Strathy Point.

NOTE.—The junctions here shown are much sharper than those of the true permeation phenomena, the softness of which it is very difficult to represent.

FIG. 2.—End of Granite Sill, Kinbrace.

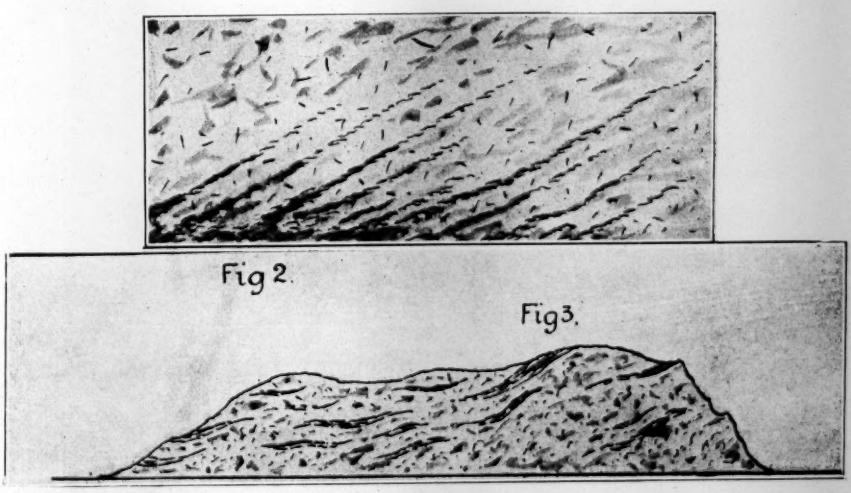


FIG. 3.—Cliff about 200 feet high, Glas Eilean, Strathy Point.

of temperature diffusion is greatly accelerated, (3) that if the temperature is kept permanently above the fusion-point of one of the substances, diffusion is still further accelerated.

It may be asked why there is any necessity to appeal to these results, seeing that we have long known that igneous magmas are intruded in a liquid state, and into remarkably narrow veins. But if ordinary igneous intrusion can account for all the phenomena under consideration, why do we not find permeation zones surrounding all intrusive rocks, even ordinary basalt dykes, for there is reason to believe that basic magmas have a high degree of liquidity?

On the other hand, it is clear that solid diffusion does not take place between rocks by mere close adpression, even after long periods of time, for junctions of normal igneous, even plutonic masses with sedimentary rocks of all ages, as well as junctions of igneous and sedimentary rocks with one another, can be seen at which no permeation whatever has taken place. Rocks do not, it is evident, diffuse with the ease that gold and lead do.

It is clear that another factor must be necessary, and this can be found, I believe, in the existence of *an already high temperature in the surrounding rocks.*

Ordinary igneous intrusions, as is shown by their chilled edges, found the rocks into which they were injected relatively cold, i.e., not appreciably above the temperature proper to a zone of the earth-crust far outside that from which the magma came. They cooled, therefore, at the margin soon after injection, and did not remain in contact at a high temperature for any length of time.

But there is abundant evidence in permeation regions that the granite at the time of injection found the surrounding rocks already at a high temperature. The junctions in Eastern Sutherland are clearly exposed in a great many places; and yet no sign of a chilled margin has been detected anywhere. The same is the case in other regions. (Indeed, "lit par lit" injection itself would appear, *a priori*, to be possible only among hot rocks, as seams so thin would soon consolidate among cold rocks, and so fail to make their way for any distance.)

If, now, we suppose a granitic magma introduced among rocks with a pre-existing temperature scarcely lower than its own (it might be even higher if the rocks were less fusible), not only would much more intimate intrusion be possible, but even when actual intrusion ceased the granite sills and the adjacent rocks would retain a high temperature at the junction for a very long time. The conditions, in fact, would be related to those of ordinary intrusion somewhat as those of a column of liquid lead poured into a hot cylinder on to hot gold would be to those of lead poured into a cold cylinder on to cold gold. Solidification would be long delayed, and all this time the magma might reasonably be expected to diffuse into the surrounding rocks, following their natural divisional planes, and giving rise to all the phenomena of a permeation zone.

The singular fact that the inclusions of gneiss in granite, even down to the thinnest films, are so very seldom, in these zones, disturbed in

position (ibid., fig. 4), affords some support for the view that the extension of the magma proceeded by quiet diffusion rather than by forcible injection.

An explanation would also be found for the occurrence of lenticles of granite in complete isolation from the parent mass.

The experiments quoted lead us to expect that diffusion might go on even after solidification, seeing that in such a complex a high temperature would be maintained for a long time, thus extending the permeation zone yet further, and in perhaps an even subtler manner. Indeed, what we know of the changes that have certainly gone on in solid rocks shows that the solid state is no obstacle to extensive molecular change.[1]

The principal difficulty would be this. The solids of the experiments were homogeneous, being pure metals, so that diffusion took place between molecules of only one kind on either side. Whether the liquid magma of a granite was a completely homogeneous liquid we do not know, but certainly after solidification no granite is a homogeneous solid. Molecules of at least three kinds would therefore, it would appear, have to diffuse in order to convey granitoid matter from place to place, and that in due proportion. This is certainly a difficulty, though not an impossibility.

Moreover, are we quite sure that solid diffusion would be obliged to proceed in this way? At the close of the paper by Mr. Horne and myself to which reference has been made, it was pointed out (ibid., pp. 647–8) how little is known of the chemistry of the compounds of silicon, and how very much may be hoped for from an extension of that knowledge, when we consider the chemical analogies presented by that element and the part which it plays in Nature.[2]

V. — Vein-Quartz and Sands.

By A. R. Hunt, M.A., F.G.S.

SOME time ago my friend Mr. Jukes-Browne asked me to examine some sand, with a view to ascertaining whether it was derived from Dartmoor. Dartmoor quartzes have so many specific characters that it is often easy to say that a quartz is not derived from that region; but owing to the fact that quartz-veins have not been studied, it is usually impossible to say whence various sands have in fact come.

In the course of conversation, Mr. Jukes-Browne suggested my submitting a short letter to the Geological Magazine, as the subject might interest students; but the more I looked at the matter the more abstruse and cumbrous did it appear; and, from past experience, I doubted whether the inquiry would not be more attractive to chemists than to geologists.[3]

[1] Hitherto we have been under the necessity of invoking the agency of percolating water.

[2] My friend Dr. Horne very kindly read the MS. of this paper, and he gives me leave to say that he agrees with the views expressed in it. Indeed, I believe it would be nearer the truth to say that he had come to similar conclusions *before* he saw my MS., and had discussed them with my former colleagues of the Scottish Geological Survey.

[3] I was unaware at the time that quartz-veins were under discussion in the Magazine.

In December, 1886, when examining marine sands, I pulverized a flint pebble and several quartz-pebbles for the sake of comparison in the microscope. I noted that the first quartz-pebble I examined was full of enclosures with bubbles. Subsequently I had more than a dozen vein-quartzes sliced. Not only did they all contain bubbles, but they all contained moving bubbles, the infallible proof of the presence of fluid. Quartz-veins and granites are near of kin, and in 1889 I wrote a paper on granite. My interest in sands and granites led me to appeal more than once to the most distinguished honorary member of our local Society, Dr. H. C. Sorby, F.R.S., who was most unsparing in his assistance in both of those subjects, which he had so long made his own. However, as might be expected, the nut proved too hard for me to crack. But Dr. Sorby's old correspondence has now put me into no slight dilemma. I cannot publish it, and I can scarcely absorb the ideas and dispense them as my own; while the last thing I should care to do would be to appear in the slightest degree to sit in judgment on the master. Yet the only points which interest me are those in which I do not quite understand Dr. Sorby; the fault being no doubt my own, if only for not having sought an explanation direct.

One point which has caused me much thought in the matter of sands is the omission by Dr. Sorby of all mention of quartz-veins as one derivation of quartz-sands, both in the addresses to the Microscopical and Geological Societies. The same doubt arises in the case of M. Delesse and the beaches of the French coast. We hear much of hyaline quartz-sand, but nothing of vein-quartzes; yet vein-quartz seems an important constituent of grits and sandstones. There are, moreover, many quartz-veins the sands derived from which could not be distinguished from sands derived from granites, seeing that water inclusions, carbonic acid inclusions, chlorides, and negative crystals are found in both varieties. We need not flatter ourselves that we can distinguish a granite quartz by its clearness and freedom from opacity. Rock crystal is the clearest of quartz, and it is no rare thing to find water-clear crystals and milky crystals lying side by side in the same drusy cavity; while between the two there may be found elsewhere every gradation. When once we begin to reflect on the whys and the wherefores of quartzes, we soon find ourselves across the borders of the known, and I feel inclined to transfer to quartz an observation by Dr. Sorby on granite, viz., that there are many things connected with it about which we know much less than is desirable.

I believe that the most important paper on the subject is still Dr. Sorby's short address of four pages to the Microscopical Society in 1876, "On the Critical Point in the Consolidation of Granitic Rocks." So far as I am aware, there are only two points in that paper that have been reconsidered, and neither of them are of material importance, so far as regards vein-quartz. Dr. Sorby followed Cagniard de la Tour in taking 412 C. as the critical temperature of water, whereas Mr. Hartley, in the Report to the British Association in 1877, treats it as being 342° C. Dr. Sorby also assumed that above the critical

temperature water-vapour would cease to act as a solvent, whereas according to subsequent experiments it appears to do so.[1] This, of course, is a most important point as regards the consolidation of minerals other than quartz; but fortunately all the authorities appear to agree that the quartzes of granites consolidated under 342°; and probably no one would maintain that the quartzes of veins represent a temperature as great as that of granitoid rocks. If all this be true, the question of vein-quartzes is very much simplified. Liquid water will dissolve a variety of minerals which water-vapour under 342° C. will reject and deposit. With water-vapour over 342° C. we need not *ex hypothesi* concern ourselves—fortunately for the length of this paper.

Writing of the variation in the proportional contents of cavities, Dr. Sorby has this very weighty passage, viz.: "The very great variation in the relative amount of water and liquid carbonic acid in the cavities clearly proves that very great changes in the surrounding circumstances sometimes took place, even during the growth of one single crystal; and there is good reason to suspect that there may often have been considerable variations in temperature and pressure, as well as in the relative amount of water and gas" ("Critical Point," etc., R. Micr. Soc., 1876). In 1889 and 1890 I wrote two papers on the granite question, and Dr. Sorby, when acknowledging receipt of one or other of them, remarked, "I very much agree with what you have said in your paper, and it now seems to me that the conditions when granite was consolidated were very complex in some cases, even more so than I urged in my paper." This view has been wonderfully confirmed by the rock Trowlesworthite, which indicates fluoric, boracic, and phosphoric acids, a regular jumble of water and brine, and two tourmalines, one probably above and one certainly below the critical temperature of water.

With respect to the evidence borne by cavities that the temperature was over 342° C., we may cite Mr. Hartley:—"In a colourless and clear topaz there were discovered thousands of perfectly cylindrical tube-like cavities, round at each end. In the case of fifty-two cavities . . . . they each contained the same proportions of carbonic acid liquid, carbonic acid gas, and water. Hence at the time they were enclosed in the mineral, these fluids must have existed in the state of a homogeneous vapour. This of necessity places the temperature of formation of the mineral somewhere above 342° C., the critical point of water" (Rep. Brit. Assoc., 1877, p. 236).

The general conclusion seems to be as follows:—

Fluid inclusions with deposited crystals are clear proof that the fluid was entangled in the quartz or other mineral, under 342° C.

Water inclusions with variable proportions of water and vacuity were also formed under 342° C.

Groups of inclusions with proportionate amounts of water and liquid carbonic acid prove a temperature exceeding 342° C.; but with disproportionate amounts of water and acid they indicate a temperature below 342° C.

[1] J. B. Hannay: Proc. R.S., 1881, p. 321.

Groups of water inclusions with proportionate amounts of water and vacuity may indicate a temperature over 342° C.; or unchanged conditions of heat and pressure during the crystallization of the including mineral, under 342° C. Pure water would suggest the first, while the presence of brine or dissolved salts would prove the second. A paper read by me at the Belfast Meeting of the British Association was founded on the idea of the heating of a district in the presence of water, with the result of forming hydrous minerals, and fluid inclusions in the altered rocks. But this was only a variant of a forgotten warning of Dr. Sorby twelve years before, viz.: "There is a point which should not be overlooked (I forget whether I alluded to it in my paper), and this is, that a rock formed under one set of conditions may have been exposed to others, and thus the state of the cavities may indicate the change produced by a reheating of rock." This seems to lead to a curious possibility, viz., that a crystal of quartz might catch up fluid with various salts in solution, such as soda, potash, and magnesia, and that on a strong reheating of the crystal the said minerals might enter into combination with the silica and form microlites. It is not uncommon to see a fissure in a crystal cemented with a brown iron oxide, which, if hydrous, would account for a good deal of water.

My collection of slices of vein-quartz is too small for any useful purpose except to indicate possibilities; but, so far as the slides go, they are very instructive. Specimens collected between Dartmouth and the Start contain one or more of such minerals as chlorite, epidote, fibrous hornblende, and triclinic felspar. Then on Dartmoor and its borders specimens of rock may be found showing every gradation from the simple quartz-vein, through veins composed of quartz-tourmaline and quartz-tourmaline-felspar (triclinic), to the quartz-felspar-tourmaline rock of normal granitic structure. In all these rocks the varying proportions of water and vacuity, and, above all, the ubiquitous presence of dissolved salts, indicate a temperature well under 342° C. One very eccentric slice from a vein in a greenstone presents the appearance of a typical satiny quartz, but under the microscope it is seen to contain innumerable water inclusions and carbonic acid inclusions. It also contains a small crystal of plagioclase, and exhibits throughout the curved shadows of a felspar. Observing that there seemed two varieties of quartz-veins near the Bolt Head, I ascertained that one was very full of fluid inclusions and the other unusually free from them. Possibly one represents the era of metamorphosis, and the other may be either older or later.

So far as I can ascertain, no one has worked the vein-quartz problem, or at any rate has published the results. Dr. Sorby showed in his first paper that the inclusions in quartz-veins in the neighbourhood of granites were intimately connected with the inclusions in the granitic quartzes themselves, but I am not aware that he has anywhere described the differences between quartz-veins of different ages and which have been subjected to different conditions. Nearly all my quartz slides are post-Devonian, and possibly post-Carboniferous, and they differ greatly from the quartzes in Culm grits and

conglomerates, and from a conglomeratic grit which, according to Mr. E. B. Tawney, is either Cambrian or Archæan. The latter is emarkable for the uniform minuteness of the fluid inclusions, and or the almost universal activity of the bubbles. For all I can see, I cannot doubt that a careful study of quartzes of different ages would furnish much useful information, bearing both on the age and origin of sands and on the origin of crystalline rocks.

There are at present so many well-trained petrologists that perhaps it is not too much to hope that some young aspirant to fame will secure a small grant for expenses, collect quartz-veins of every obtainable age, and exhaust all the information that can be squeezed out of them. The most important papers on the subject after Dr. Sorby's classic paper in the Q.J.G.S. of 1858 are the same author's address to the Microscopical Society in 1876, and Mr. Hartley's papers on fluid inclusions to the Royal and Chemical Societies and his Report to the British Association in 1876 and 1877. Perhaps the chief thing to bear in mind as a spur to attack these much shirked problems is Dr. Sorby's final word, viz., "there are many things connected with [the subject] about which we know much less than is desirable."

VI.—The use of a Geological Datum.

By Beeby Thompson, F.G.S., F.C.S.

A PROPER interpretation of some geological phenomena requires that allowance shall be made for differential earth-movements that have taken place since the period of occurrence of the events or conditions under consideration.

Present differences of level in rocks of the same age may be partly due to actual differences in depth of the sea-floor on which they were deposited, but they may also be the results of subsequent differential earth-movements either of a regional or of a local character, the latter including 'faults.'

In order to estimate the amount of displacement or differential movement, it is necessary to select a particular rock as a datum. The rock selected should combine, as far as possible, the following characteristics:—

1. It should be comparatively thin.
2. It should have a considerable horizontal extension.
3. It should combine similarity in physical characters and palæontological contents over a large area, so that uniformity of depth of deposit may be postulated.

In the district with which I am best acquainted, Northamptonshire, either of three formations would fairly well meet the requirements named above for certain purposes, viz., the Rhætic Beds, the Marlstone Rock-bed, and the Cornbrash. For a particular object I selected the Marlstone Rock-bed as the most suitable datum, and the results obtained by its use in this manner are, I think, sufficiently interesting to record, since they appear to justify the selection and the method of use.

It is fairly well known that one deep shaft and four deep borings have been made within Northamptonshire, two in search for coal and three for water.[1] The best readily available account of these is contained in a paper by the late Mr. H. J. Eunson, published by the Geological Society.[2]

Below is given an abbreviated and rearranged account of these five sections in accordance with information contained in the paper above referred to, together with certain corrections which it is the partial object of this paper to justify.

SUMMARY OF DEEP BORINGS IN NORTHAMPTONSHIRE.

Distance in feet above or below Ordnance Datum.

Name of Formation, etc.	Gayton.	Northampton, L. & N.W. Ry. (corrected).	Northampton, Kettering Road.	Kingsthorpe (old section).	Kingsthorpe (corrected).	Orton.
Surface of the ground	+282	+191	+278	+374	+374	+374
Top of the Middle Lias	+274	...	+107	+164	+108	+326
Top of the Rhætic Beds (White Lias)	−299	−405	...	...	...	−292
Top of the Trias (including Littoral Beds)	−335	?	−460	−486	−486	−314
Old Land Surface...	−417	−455 ?	−527½	(below −593	below −593)	−341
Top of the Carboniferous Formation	−417	−455 ?	−527½			
Top of the Old Red Sandstone ? ...	−607					
Top of the Archæan Rocks ...	...	...	...	...	...	−341
Bottom of section	−712	−459	−573	−593	−593	−415

Thickness in feet.

Superficial deposits	7	26	4	206	266	10
Oolitic Beds	...	...	14			
Upper Lias	1	...	153			38
Middle and Lower Lias	573	570	567	654	594	618
Rhætic (including Littoral Beds of Rhætic age)	36	50	67½	107	107	22
Trias (including Littoral Beds of Triassic age)	82					27
Lower Carboniferous Rocks ...	190	4	45½			
Old Red Sandstone ?	105					
Archæan (volcanic rock)	...	...	...	...	...	74
Total thickness	994	650	851	967	967	789

In the preceding Summary of Borings I have grouped various beds together where there might be a difference of opinion as to their individual limits, and where so doing does not affect the objects of this paper. For instance, in three of the sections —

[1] For convenience we will speak of all as borings.

[2] Henry John Eunson, F.G.S., "The Range of the Palæozoic Rocks beneath Northampton": Quart. Journ. Geol. Soc., vol. xl, pt. 3, No. 159, pp. 482–496.

Gayton; Northampton, Bridge Street; and Northampton, Kettering Road—the Middle Lias is described in Mr. Eunson's paper as "Middle Lias (rock-beds)," and the thicknesses are given as 20, 20, and 21 feet respectively; all below, for some 550 feet, coming under the title Lower Lias Clay. No doubt, actually, the Middle Lias, that is to say, all beds between the 'Capricornus' zone below and the 'Serpentinus' zone above, is close upon 100 feet thick, but no information is available to fix the lower limit precisely in any of the borings.

The Littoral Beds are of somewhat different ages in the different places, but have been grouped with the Trias or the Rhætic for convenience.

Firstly, on reference to the Summary of Borings in Northamptonshire, it may be observed that whilst the Old Land Surface now varies in height by more than 252 feet, the variation in thickness of the rocks between it and the top of the Middle Lias only reaches 66½ feet plus so much more as would require adding on to the 252 feet also.

Secondly, it will be noticed that the Old Land Surface is lowest where the Rhætic beds have not been detected, which appears rather singular. Mr. Eunson observed this, and made the following remark thereon (p. 494): " . . . but the Kettering-road boring shows a great depression. This may partly account for the absence of the White Lias and Rhætic, and the sandy appearance and uneven bedding which the lower part of the Lias Clay presented in this boring, and which was not noticed at either Orton or Gayton."

My inability to understand in what way a quite local depression could lead to an entire absence of certain characteristic marine beds developed to a thickness of 36 feet within about five miles (Gayton), and to sandy conditions of the Lower Lias, led me to make the following simple calculations. Assuming that the well-marked Marlstone rock-bed was deposited under uniform conditions as to depth within the area under consideration, and taking it as a datum, then, according to the figures quoted in the Table of Borings, relatively to Northampton, Gayton has since been raised 167 feet and Orton 219 feet. A correction made on this basis altogether changes the appearance of things. The Old Land Surface at Northampton, instead of being 110½ feet *lower* than at Gayton and 186½ feet *lower* than at Orton, becomes 56½ feet and 32½ feet *higher* than at these places respectively. The following table will graphically show this.

Of course, in an argument of the nature here presented, it is impossible to say how much of the difference of level is due to upward movement of one place, and how much to depression of another with which it is compared; therefore the selection of a section for reference is arbitrary. Having selected the Kettering Road boring, Northampton, we will make a few comparisons between this and each of the others, together with some observations arising out of them.

TABLE SHOWING VARIATIONS OF LEVEL DUE TO EARTH-MOVEMENTS.

Height from Ordnance Datum in feet.

	Gayton.	Northampton.	Orton.
Present actual levels: top of Middle Lias	+274	+107	+326
,, ,, Old Land Surface	−417	−527½	−341
Restored relative levels: top of Middle Lias	+107	+107	+107
,, ,, Old Land Surface	−584	−527½	−560
Significant records	Rhætic Beds, 36 feet.	No Rhætic Beds.	Rhætic Beds, 22 feet.

Gayton.—After having made our correction for earth-movements subsequent to the Middle Lias period, if we pile the 82 feet of Trias and Littoral Beds on to the Old Land Surface at Gayton, and the 67½ feet of similar beds on to it at Northampton, it will still leave Northampton 42 feet the higher, an amount of difference in level sufficient to entirely exclude the 36 feet of normal Rhætics found at Gayton only about five miles away, in strict accordance with our specification of a datum rock, though very probably the upper portion of the Littoral Beds at the Kettering Road are of Rhætic age. The addition of 36 feet of Rhætic beds at Gayton would, however, bring the levels of the two localities, Gayton and Northampton, within 6 feet, consequently this is the amount of difference in aggregate thickness of the Middle and Lower Lias at the two places (see Table). A very small amount, it will be observed, out of 570 feet, considering that the places are about 5 miles apart.

Northampton (Kettering Road).—It follows from the above considerations that the Littoral Beds at the Kettering Road boring, Northampton, may be of an age extending from the Triassic, through the Rhætic, even into the Lower Liassic periods. This will help to explain the abnormal character of the deposits themselves, and also the sandy nature of the lower beds of the Lower Lias there, for, no doubt, land remained exposed and the sea shallow to a still later period than at Northampton, not far away.

Northampton (London and North-Western Railway, Bridge Street Station).—The account of this boring left by the Rev. C. H. Hartshorne[1] runs as follows:—

	feet.
Superficial accumulation, consisting of detrital gravels, dark tenacious clays with erratic boulders	46
Lias blue clay with bands of stone	550
Very hard pyritous rock	1
Variegated sandstone (viz., red, green, and white), with 15 feet of limestone	46
White sands	3
Magnesian limestone	4
Total	650

[1] Rev. C. H. Hartshorne: "A Report on the Drainage of the Nene Valley"; Northampton, 1848.

Salt water came from the bottom of the boring and rose to within 8 feet of the surface.

This boring is situated about two miles from the Kettering Road boring, and in a nearly direct line between the latter and Gayton boring. It is on the south side of the Nene 'fault,' and not far removed from it; also, notwithstanding that the Marlstone rock-bed is not present, or at least was not recognized, I am convinced that the Middle Lias is nearly complete, the upper part being represented by what is described above as "dark tenacious clays with erratic boulders" to the extent of about 20 feet out of the 46 feet. This belief is founded on personal inspection of material brought up from a well on the same side of the Nene 'fault,' starting at approximately the same level above O.D. and only about a quarter of a mile away to the north, at Messrs. Phipps' Brewery, and from the fact that at two places a little nearer the line of the river Nene alluvium and gravel combined had the thickness of 27 feet and 28 feet respectively.

Referring again to the same section, when it became evident that the combined thickness of Middle and Lower Lias was nearly identical with the thickness of the same formations at Gayton (see Summary of Borings), then also it became highly probable that the *very hard pyritous rock*, 1 foot thick, immediately under the Lower Lias was the equivalent of the *hard white limestone with pyrites*, 1 foot thick, similarly situated at Gayton,[1] both, in fact, constituting the top of the White Lias.

Levelling each of these rocks to a Marlstone datum of + 107 feet O.D., as in previous instances, we get the Gayton hard limestone coming out as —466 O.D., and the Northampton, Bridge Street, hard pyritous rock as —463, or a few feet below this if we make allowance for the slight imperfection of the Middle Lias there. Anyway it is obvious that these rocks were deposited at practically the same depth at the same time. Thus the Rhætic beds are virtually brought into Northampton, and the suggested cause of their absence in normal form two miles away, at the Kettering Road boring, is made a certainty.

Orton.—After correcting for the post-Liassic earth-movements (p. 218), and placing on to the Old Land Surface at Gayton 118 feet, and at Orton 49 feet (aggregate of Trias, Littoral Beds, and Rhætics), then the top of the Rhætic beds at Orton would be 45 feet lower than at Gayton; and it might be asked why, in accordance with the gist of this paper, the whole of the Rhætics are not present at Orton, or inversely why any whatever are present at Gayton. I cannot here deal with the whole subject involved in an answer to such a question, but chiefly and briefly my reply is this:—Orton, at the close of the land period, was *higher* than Gayton (smaller thickness of Trias and Littoral Beds); at the latter end of the Rhætic period at about the *same level* (indistinguishable nature of some of the deposits from the two places);

[1] Henry John Eunson, F.G.S., "The Range of the Palæozoic Rocks beneath Northampton": Quart. Journ. Geol. Soc., vol. xl, pt. 3, No. 159, p. 486.

in Lower Lias times *lower* (greater combined thickness of Middle and Lower Lias), because it, i.e. Orton, lay further to the north-west of that line or direction about which, as a fulcrum, a general north-westerly sinking was taking place at the time under consideration, than either Gayton or Northampton.

The almost identical thickness of combined Lower and Middle Lias at Gayton and Northampton would lead us to judge that these places were actually on the line of fulcrum, or one parallel to it, and since they are almost accurately south-west and north-east of each other respectively, that direction may be looked upon as the general direction of the axis of movement.[1]

Kingsthorpe.—The shaft at Kingsthorpe was made in a search for coal, in 1836. According to the late Mr. S. Sharp, F.G.S.,[2] "No accurate detailed section of the shaft was taken at the time; but at a depth of 210 feet from the surface, a water-yielding 'limestone rock' in the Middle Lias (Marlstone) was pierced, which produced 36,000 gallons of water per hour. At a depth of 880 feet (as is stated in pencil notes on a diagram in my possession, which notes are said to have been made by Dr. William Smith, 'the Father of English Geology') the New Red Sandstone was reached, and a flow of brackish water of a like volume to the former occurred."

It is quite certain that the above description of the Kingsthorpe shaft is in error somewhere, for, taking the figures as they are given, (*a*) of the 210 feet down to and through the rock-bed of the Middle Lias, the Upper Lias would absorb 180 feet or more, leaving less than 30 feet for all beds between it and the Great Oolite Limestone, whereas in the near neighbourhood they are considerably more than twice this thickness; (*b*) the top of the Middle Lias appears as 57 feet higher than at the Kettering Road boring; (*c*) the Middle and Lower Lias have an aggregate thickness of 654 feet compared with 567 on the Kettering Road, a difference of 87 feet in just over a mile.

Applying the Marlstone datum to Kingsthorpe, the results come out as below. Take + 107 feet O.D. as the top of the Marlstone rock-bed at Kingsthorpe, the same as at the Kettering Road boring quite near, and we get 267 feet (374 — 107) as its depth; give the rock a thickness of 4 feet, and it is evident that it would be pierced at 271 feet from the surface. In 1881 the Kingsthorpe shaft was opened up by my advice, to see if it were yielding any water from the Marlstone at 210 feet or thereabouts; it was not, but salt water filled the shaft to within 270 feet of the surface exactly. Putting these two items together, the inference is very forcibly driven home that someone has mistaken 270 for 210 in reading the records of the shaft, a thing very likely to happen.

Personally, I have no doubt that the error suggested above occurred, because, after making the correction, the general accuracy

[1] See also "The Victoria History of the Counties of England: Northamptonshire," Geology, vol. i, p. 8.

[2] "Note on a futile search for Coal near Northampton": Geol. Mag., Vol. VIII, p. 505.

of the original record of the Kingsthorpe shaft becomes very probable; all difficulties of interpretation are removed; and we can give to the various formations their necessary thicknesses and reasonable positions above O.D.

The fact that in 1881 salt water filled the Kingsthorpe shaft to within 270 feet of the surface is suggestive; it would indicate that the Marlstone rock-bed then determined the height to which the water could rise, and, therefore, that salt water was then feeding the Marlstone to some extent; indeed, it is almost certain that, according to the amount of pumping going on at Northampton, the Kingsthorpe shaft may feed or be fed by Marlstone water. Fortunately, the supply of salt water is very moderate, and the greatest variation in chlorine I have observed in the Marlstone water is 1·61 grains per gallon. In 1879, when Marlstone water was used almost exclusively for the town supply, the water yielded 5·6 grains of chlorine and 50·5 grains of solid matter per gallon; in 1897, when it was used intermittently, the chlorine came out as 3·99 grains per gallon, and solid matter 48.

Before giving a revised section of the Kingsthorpe shaft, I must justify another alteration to be made in the figures, etc. The *Mining Journal* of September 3rd, 1854, in a description of the Kingsthorpe undertaking, after giving an unintelligible classification of the beds above, says that the Lias formation "was followed by 84 feet of New Red Sandstone, 13 feet of Red Marl, and 15 feet of Conglomerate." This description was quoted in the 1854 prospectus of "The Northampton Great Central Coal Mining Company."

Mr. Sharp, in one place, says[1] that the *blue clay of the Lower Lias was pierced at* 860 *feet*, and is stated to have been succeeded by 80 feet of Sandstone, 12 feet of Red Marl, and 15 feet of Conglomerate; in another[2] he says that *at* 880 *feet the New Red Sandstone was reached.* My opinion is that all three descriptions are essentially correct, and that the difference of 20 to 24 feet of beds, which the geologists could not decide what to call, is the equivalent of the Littoral Beds, 27 feet thick, above the Trias at the Kettering Road boring, about which, and other beds below, Mr. Etheridge said, "no equivalents in Britain," "no series like them" (Eunson, p. 484). That these undefined beds at Kingsthorpe contained conglomerates is evident, for in Miss Baker's collection of fossils was a specimen of conglomerate consisting of limestone pebbles in a greenish, sandy, and highly calcareous matrix, some parts hard and crystalline, labelled "Top of Red Sandstone *upwards* of 900 feet, Kingsthorpe shaft," a label which until recently I could not understand.

In the revised section given below, the Upper Estuarine Beds, Lower Estuarine Beds, and Ironstone Beds (not all ironstone.

[1] "The Oolites of Northamptonshire," part i: Quart. Journ. Geol. Soc., March, 1870.

[2] "Note on a futile search for Coal near Northampton": Geol. Mag., Vol. VIII (1871), p. 505.

however) are given to the nearest foot from the record of a well recently made (1902) just over one mile away to the east.

Old Section.	Thickness in feet.	Revised Section.	Thickness in feet.	Depth of base in feet.	Height of top from O.D.
Rocks down to and through the Rock-bed of the Middle Lias	210	Superficial Beds	8 ?	...	+374
		Upper Estuarine Beds...	26		
		Lower Estuarine Beds...	31		
		Ironstone Beds (stated to be 35 feet)	21	86 ?	
		Upper Lias	180 ?	266 ?	+288 ?
Middle and Lower Lias	650	Middle Lias	100 ?	366 ?	+108 ?
		Lower Lias, with stone bands towards the base	494 ?	860	+8
Sandstone ...	80	Littoral Beds, including conglomerates	20	880	−486
		Red Sandstone	60	940	−506
Red Marl ...	12	Red Marl	12	952	−566
Conglomerate	15	Conglomerate	15	967	−578
	967	Total depth ...	967		

In conclusion, it may be pointed out that, beyond the direct object of the paper, several little points in local geology have been cleared up or made more intelligible. Perhaps the most generally useful result is the demonstration that a levelling up process was going on just before the commencement of the Lower Liassic period, which culminated in the Rhætic beds (White Lias), and that a similar levelling took place at the close of the Middle Lias period, though this was perhaps as much a result of redistribution of material in shallow water, a give and take process, which ultimately led to the very uniform conditions of the 'Acutus' zone (Transition bed) at the top of the rock-bed of the Middle Lias.

VII.—Note on the Millstone Grits of Grassington Moor.

By J. R. Dakyns.

THE Millstone Grits of Grassington consist, speaking generally, of the beds given in the following table, viz. :—

Grit of Henstone Band.
Measures.
Thin limestone.
Redscar Grit.
Measures.
Sandstone.
Measures.
Sandstone of Priest Tarn.
Measures.
Coal and shale.
Top Grit of Grassington Moor.
Shale and coal.
Bearing Grit of Grassington Moor.

As throughout the greater part of Upper Wharfedale the Bearing Grit lies immediately on or close to the Main Limestone of Phillips'

Yoredale Series, we have here a well-marked and natural division between the Yoredale Beds and the Millstone Grit.

The Bearing Grit is so called because the lead veins are very rich in this bed.

A tolerably persistent coal, ranging up to ten inches in thickness, occurs in the overlying shales, and a coal up to six inches thick lies on or near to the Top Grit.

The sandstone of Priest Tarn probably corresponds to a bed which further north forms Pinlow Pike, and is in Coverdale, though thin, very persistent and of a well-marked character, being a hard siliceous rock.

The next important rock is the bed we call the Redscar Grit. It is a coarse felspathic grit of a very red tinge, which is apt to form such conspicuous red scars that it can be recognized miles off. This rock, like the Grassington group, often consists of two members parted by a shale band containing a coal-seam, and it thus forms a double feature. In this part of the country it generally has on or near its top a thin bed of peculiar limestone that has the appearance of a tesselated pavement. This tesselated limestone forms a very good horizon as the top of the rock, which we correlate with the top of the Kinder Scout Grits.

The next important rock is that which forms Henstone Band. We correlate it with the lower grit of Follifoot Ridge.

I will now briefly describe the run of the principal beds. Immediately north of the Craven Fault the Lower Millstone Grits strike west from Bewerley across Grimwith Fell towards Grassington. Near this village they turn north and run by the mines across Grassington Moor, Black Edge, and Coniston Moor. They are thrown down to the north of Yarnbury by the New Rake Vein, then up by Beaver Vein, and after several small breaks are finally thrown up on the north by the Bycliffe or Black Vein.

This great vein runs from Bycliffe along Groove Gill, crosses Gateup Gill, where the fracture is seen, and thence crossing north of Wigstones it runs down Stony Groove to Merrifield, and thence into the Craven Fault near Pateley Brig. This vein is the most northerly and greatest in throw of the many veins on Grassington Moor. They seem all to be more or less connected with the Craven Fault, to which they are roughly parallel or with which they make small angles.

The Redscar Grit occupies the northern part of Appletreewick Moor and Hebden Moor. It forms a fine escarpment along the sides of Gateup Gill. It is thrown up to the north by the Bycliffe Vein so as to form the escarpment of Rather Standard, at the north end of which it is thrown up on the west, so that the top of the rock, which runs up Henless Beck, is now found in Meugher Dike. This top is well marked by the tesselated limestone which is found in place in Henless Beck and in Meugher Dike.

The rock forming Sand Haw seems from its position to be part of the Redscar Grit. It is a peculiar rock, being hard, close-grained, and siliceous, and is used for making whetstones, for which purpose

it is, or used to be, transported for long distances. It is somewhat similar to the Redscar Grit of Wolfry Crags, but is quite unlike the general character of this bed.

It is noteworthy that I found near the base of the Redscar Grit in Gateup, bands of calcareous sandstone. Similar bands, as I am informed by Mr. J. G. Goodchild, generally occur under the rock which in Wensleydale was identified on purely stratigraphical grounds with the Redscar Grit.

This grit is the 'middle grit' of the late Professor Phillips mentioned on p. 65 of his "Geology of the Mountain Limestone District," and he is quite correct in saying that it corresponds in position with the top grit of Penhill.

NOTICES OF MEMOIRS, ETC.

On the Evolution of the Proboscidea. By C. W. Andrews, D.Sc., F.G.S., F.Z.S., of the Geological Department, British Museum (Natural History).[1]

UNTIL the author's recent discoveries of primitive Proboscidea in the Middle and Upper Eocene formations of the Fayum, Egypt, the oldest known members of this mammalian order were *Dinotherium Cuvieri* and *Tetrabelodon angustidens*, from the base of the Miocene in France. The new Egyptian fossils not only reveal for the first time the early history of the order, but also provide more satisfactory material for the discussion of its evolution than has hitherto been available.

The most important changes in the Proboscidea occur in the skull, mandible, and dentition.

Owing to the increase in the size of the tusks and to the presence of the proboscis, the facial region of the skull becomes shortened, and at the same time the premaxillæ become wider. The presence of the proboscis also accounts for the position of the external nares. The demand for a greater surface of attachment for the muscles supporting a skull rendered heavy by the tusks and trunk, is met by the great development of the diploë in certain of the cranial bones, resulting in the enormous expansion of the forwardly sloping occipital surface. The maxillæ become greatly enlarged concomitantly with the increase in the size and degree of hypselodonty of the molars. At the same time the zygomatic arch becomes weaker and the jugal takes a smaller share in its composition.

The mandible is at first short and stout, with a massive symphysis. Afterwards it becomes more and more elongated as the stature of the animals increases; and this elongation is for the most part effected by the lengthening of the symphysial region, though the backward rotation of the ascending ramus tends to the same end. The prolongation of the mandible beyond the premaxillæ must have been covered by a proboscis-like structure composed of the upper lip and nose, probably more or less prehensile at its extremity.

[1] Abstract of a paper read before the Royal Society of London, March 26th, 1903; communicated by Professor E. Ray Lankester, F.R.S.

The lengthening of the mandible seems to have reached its maximum degree in the Middle Miocene, after which it again became shortened by the reduction of the symphysis, while the fleshy and now mobile proboscis was left behind as the sole organ of prehension.

In the upper dentition the chief changes are the loss of incisors Nos. 1 and 3, and the great increase in size of incisor No. 2, which eventually forms the great tusk characteristic of the later Proboscidea. The canines are soon lost. In the earliest forms, some at least of the cheek-teeth (milk-molars) are replaced by premolars in the usual manner, and these teeth remain in wear simultaneously with the true molars; but in later forms no vertical succession takes place, and as the milk-molars are worn they are shed, being replaced from behind by the forward movement of the molars. Of these also the anterior may be shed, until at length in old individuals of the later types the last molar is alone functional. The gradual increase in the complexity of the proboscidean molars is one of their most striking characteristics. All stages can be traced between the simple, brachyodont, bilophodont (quadritubercular) molars of *Mœritherium* (Middle Eocene) to the extraordinarily complex type of tooth found in *Elephas*. Thus in *Palæomastodon* (Upper Eocene) the molars are trilophodont, and the same is true of the first and second molars of *Tetrabelodon* (Miocene), in which, however, the last molar is complicated by the addition of further transverse crests. In the Stegodonts of the Siwalik Hills (Pliocene) a further increase in the number and height of the crests takes place, and the whole crown of the tooth is more or less covered with a thick coat of cement. Still later, the transverse crests become highly compressed laminæ united by cement, and these are as many as twenty-seven in number in the Pleistocene *Elephas primigenius* and the recent *E. indicus*.

The evolution of the lower molars corresponds with that of the upper molars. Of the lower incisors the middle and outer pairs (Nos. 1 and 3) are soon lost, but the second pair remains functional for a long geological period. When the symphysis becomes shortened, these incisors are sometimes retained as vestiges (e.g. in *Mastodon americanus*), but in the genus *Elephas* they have completely disappeared.

REVIEWS.

I.—Chart of Fossil Shells found in connection with the Seams of Coal and Ironstone of North Staffordshire. By Wheelton Hind, M.D., F.R.C.S., F.G.S., and John Stobbs, F.G.S. (Published by the North Staffordshire Institute of Mining and Mechanical Engineers, 1903. Price 5*s*.)

IT is an acknowledged fact that, compared with many other commercially less important geological formations, very little is known about the distribution of the fossils among the Coal-measures. In this respect the North Staffordshire Coalfield has been more carefully searched than others, though outside the

district this typical Midland coalfield is not so well known as the excellence of the sequence and preservation of its organic contents warrant. The chart by Messrs. Hind and Stobbs should draw attention to this region, for besides being of use to the mining student it will be found to be of more than local value, and should be studied by all interested in the Coal-measures.

The chart gives the order of sequence, distance apart, and synonyms of the seams of Coal and Ironstone of the Pottery and Cheadle Coalfields, in two sections drawn on a scale of 200 feet to the inch. The fossil shells distinctive of or especially abundant on certain horizons are drawn opposite to the particular bed in which they occur. No attempt has been made to subdivide the Coal-measures beyond the use of merely local terms for the higher portion of the sequence. Marine organisms are represented as occurring on three horizons—at the base, near the middle, and towards the summit of the coal-bearing strata. A noticeable omission, evidently due to extreme caution, is the band, rich in marine organisms, found many years ago by Mr. John Ward above the Gin Mine at Longton. Thin limestones with *Spirorbis*, so long held to be distinctive of the higher Coal-measures, are represented at two horizons low in the sequence. The fossils are clearly drawn, while their selection by Dr. Wheelton Hind guarantees that the typical forms have been chosen.

The authors have evidently taken great care in planning and drawing up the chart: it is to be hoped the Mining Institutes in other coalfields will follow the example of that of North Staffordshire by publishing similar charts, and thus show that they recognize the close union of the two sciences of Mining and Geology.

WALCOT GIBSON.

II. — CAPE OF GOOD HOPE. ANNUAL REPORT OF THE GEOLOGICAL COMMISSION, 1900. 4to; pp. 93. (Richards & Sons, Cape Town, 1901.)

I. The results of the survey of parts of the Uitenhage and Port Elizabeth districts (pp. 1 to 18). The Sunday's River Marine Beds, the Wood-bed series, and the Enon Conglomerate series constitute the great *Uitenhage* series; and these were studied in the Zwartkop Valley, the Bezuidenhout Valley, and on the White River and the Sunday's River. The fossil fauna and flora are referable to both the Jurassic and the Cretaceous series; and are here provisionally regarded as Upper Jurassic. The occurrence of much more recent deposits near the coast are alluded to. The observations made by earlier geologists on the district are carefully noted.

II. (Pages 19–54.) A survey of parts of Clanwilliam, Van Rhyn's Dorp, and Calvinia divisions led to the definite recognition of a separate series of sedimentary rocks (shales, sandstones, vein-quartz, quartzite, limestone, and conglomerate) underlying the Table Mountain Sandstone, and resting on the Malmesbury series. The conglomerates are decidedly glaciated, and much resemble those of the Congo in Oudtshoorn in some respects. The sandstones,

false-bedded and ripple-marked, show worm-casts and definite animal trails. This *Ibiquas* series (named after a local tribe of natives) extends from the north-eastern part of Van Rhyn's Dorp district into Calvinia; it appears to be much thicker than the Bokkeveld series, which in places is seen to be unconformable above it.

In this survey we have also an account of the local range of the Table Mountain Sandstone, the Bokkeveld Beds, the Dwyka series, and its continuation to Prieska and Hope Town. The peculiar *White Band*, lying on the Dwyka Conglomerate, owes its appearance to the slow combustion of a carbonaceous shale under atmospheric agencies. The thick shales and sandstones of the Ecca series, above the White Band, contain some ferns and calamites in the south. The local dykes and sheets of Dolerite are described in detail. They all belong to one series of intrusions; and, like the Karoo dolerite type, consist of a moderately coarse plagioclase-augite-olivine rock.

III. The survey from Beaufort West to Calvinia (pp. 55 to 64) showed mostly horizontal beds of the Karoo series of shales and sandstones, pierced vertically and horizontally with dykes and sheets of the usual dolerite. The shape and constitution of the hills very much depend on the presence of this intrusive rock and the peculiar modes of its weathering. A remarkable cylindrical hole, near Ratel Fontein, in sandstone and shale, is filled with rocks and minerals such as are found elsewhere associated with diamonds, but they are absent here.

IV. (Pages 65 to 79.) The geology of the Cedarbergen and adjoining country between the Gydr Pass on the south and the Pakhuis Pass on the north comprises the Table Mountain Sandstone, the Bokkeveld, and the Witteberg series. In the Table Mountain Sandstone (Lower Devonian) of the Pakhuis Pass there is undoubted evidence of local glacial action contemporaneous with the deposition of the sandstone and shale or mudstone, with glaciated pebbles in early Devonian times.

In a separate paper on this Glacial Conglomerate in the Table Mountain Sandstone read before the South African Philosophical Society in February, 1901, Mr. A. W. Rogers gave further particulars as to the character and condition of this deposit, illustrated by a plan and section (Trans. S.A. Phil. Soc., vol. xi, pt. 4, pp. 236–242). He states that "The shale band was first recognised by Mr. Schwarz in the Hex River and Warm Bokkeveld Mountains. In the 1st Ann. Rep. Geol. Comm. C.G.H. for 1896, p. 27, he describes two shale bands, one near the Table Mountain Sandstone and the other near the bottom: the upper of these two is the one referred to above. The course of this band between the Schurftebergen and Pakhuis is described in the 5th Ann. Rep. for 1900."

The results of 1900 were obtained under very disadvantageous circumstances owing to the War, but they have been welcome additions to geological knowledge: (1) especially as to the relationship of the Ecca series and the associated so-called Dwyka Conglomerate

to the formations above and below; (2) the existence of a separate formation (Ibiquas) between the Table Mountain Sandstone and the Malmesbury Schists; (3) a definite glacial conglomerate in the Table Mountain Sandstone; (4) the careful and systematic examination of the probably Upper Jurassic in the East Province round about Uitenhage confirms and gives welcome additions to what was known before.

The work has been done by A. W. Rogers and E. H. L. Schwarz. Dr. Corstorphine, while Director of the Survey, made the useful report before us, and on his resignation, we understand, was succeeded by Mr. Rogers. We have no doubt of the further good progress of this Survey. T. R. J.

III.—British Museum. A Guide to the Antiquities of the Stone Age in the Department of British and Mediæval Antiquities. Pages xii and 124, with ten plates and 142 illustrations. (British Museum, Bloomsbury: printed by order of the Trustees, 1902. Price 1*s*.)

MR. CHARLES H. READ, F.S.A., the Keeper of British and Mediæval Antiquities, who is the author of this admirable Guide, has conferred a great service on the ordinary Museum visitor, who "wants to know," and is at a loss to find out for himself the hidden meaning of things. He is like the Ethiopian eunuch of old and wants some man to guide him. Mr. Read kindly comes forward and at once the difficulties of understanding the collection disappear.

Fig. 1.—Triangular implement, Herne Bay. (Fig. 6, p. 18 in Guide.) ½ nat. size.

The period in human history represented by the 'Stone Age' is just that most difficult of all chapters to write, because the evidence is so largely inductive, and depends for the earlier or

Palæolithic period to so great an extent upon geological data, that one would naturally expect to have to pay a visit to the Cromwell Road Branch of the British Museum at South Kensington in order to understand the stratigraphical aspect of our Earth in relation to early Man as one of its inhabitants. Mr. Read, however, in the first 14 pages of his Guide, gives us an excellent resumé of the Palæolithic period, and takes us back first to the discovery by Mr. Conyers (at the end of the seventeenth century) of a flint implement, in gravel, near Gray's Inn Lane, London, together with an

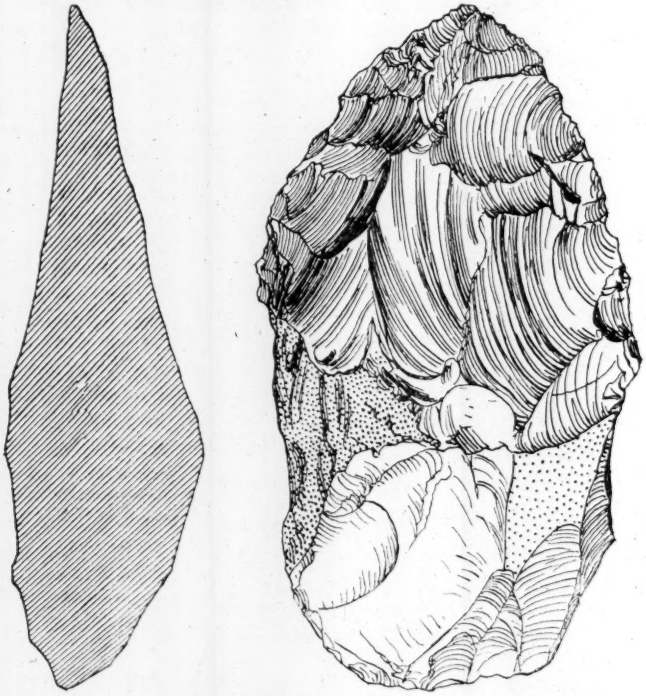


Fig. 2.—Shoe-shaped implement, Northfleet. (Fig. 8, p. 19 in Guide.) $\frac{2}{3}$ nat. size.

elephant's tooth; and then on to Mr. John Frere's researches a century later (1797), and the finding of flint implements in river gravel at Hoxne, Suffolk, which the discoverer referred "to a very remote period indeed, and to a people who had not the use of metals." No other records occur of finds in valley gravels until M. Boucher de Perthes' exploration of the deposits of the Somme Valley at Abbeville (1850), where large quantities of implements evidently fashioned by the hand of man were found.

It is due, however, to the Rev. J. McEnery (a Roman Catholic priest living at Torquay, S. Devon) to mention that, so far back as 1825,[1] he had discovered (*not* in river gravel, but) in Kent's Cavern,

[1] Published by E. Vivian, Esq., 1859.

Torquay, evidences of man in the form of flint flakes and stone implements, associated with the remains of Hyæna, Reindeer, Cave-bear, and the sabre-toothed Tiger or Lion (the *Machærodus*), together with the Mammoth and Rhinoceros.

The truth of McEnery's discoveries remained unverified until forty years afterwards, when Pengelly's exploration of Kent's Cavern placed the accuracy of McEnery's original observations beyond a doubt. The stone implements sent up to Professor Buckland eighty years ago by McEnery seem to have disappeared, but the remains of *Machærodus* and Hyæna were preserved, and testify to the value of his work as an original observer and discoverer of early Man.

Fig. 3.—Chert implement with curved edges, Broom, Dorset. (Fig. 15, p. 25 of Guide.) ½ nat. size.

A diagram is given by Mr. Read (on p. 2) to show the evidence as to the geological antiquity of the river-valley gravels containing the flint implements in the valleys of the Somme, the Thames, and elsewhere. Contrary to other geological evidence, based upon superposition (where one would at once naturally conclude that the highest beds were the newest, and the lowest the oldest), in these river-valley deposits it is the oldest beds of gravel which occupy the highest of the old river-valley terraces, and the newest gravels which lie in the bottom of the present river valley. The explanation is so obvious that (like the story of Columbus and the egg) everyone sees it must be so, when told that the river in the course of centuries has gradually deepened its valley, and that whereas it formerly flowed perhaps hundreds of feet above its present level, it has, by its slow erosive action (aided by rain, frost, and snow), cut its channel lower and lower, until it has reached the depth at which we find it flowing to-day. But the river, in wandering in its serpentine course along its valley, leaves behind upon its flanks portions of its earlier and

more elevated level in the shape of terraces covered with beds of old river-valley gravel (containing flint implements), of which the highest is really the oldest. Even outside the limits of its valley we find that still older watercourses have flowed along, and in places spread sheets of gravel over the plateau far above the reach of any modern flood-waters. In this *very ancient gravel* implements of a far ruder type than those commonly known as 'Palæolithic' are met with. These have been accepted as weapons made by some early and most uncivilized race of mankind, and are termed 'Eoliths,' good examples of which, collected by the Rev. R. Ashington Bullen, may

Fig. 4.—Chopping tool, province of Poitou. (Fig. 29, p. 32 in Guide.) ½ nat. size.

be seen figured in Plates VI and VII of this Magazine for March last (pp. 102–110). "It is not" says Mr. Read (p. 10), "the province of the present Guide to enter into the arguments which have been brought forward against or in favor of the artificial character of Eoliths, but it may be said that whether their claims can be substantiated or not, the existence of implements of a ruder kind than those of the drift is in itself not improbable. For no invention reaches perfection suddenly, and each stage of advance is attained by an infinitely slow progress from the simple to the more

complex. The majority of the drift implements are clearly something more than the first efforts of an unpractised hand; they show, on the contrary, signs of a comparatively long development, and it may be fairly argued that their ruder prototypes must exist somewhere.

FIG. 5.—Axe-head with hollowed edge, Denmark. (Fig. 96, p. 89 of Guide.) $\frac{2}{3}$ nat. size.

FIG. 6.—Flint chisel, Denmark. (Fig. 97, p. 89 of Guide.) $\frac{1}{3}$ nat. size.

It was to be expected that they should have escaped notice for a longer time than the typical Palæoliths, if only because they must necessarily be more difficult to distinguish from the naturally fractured flints.

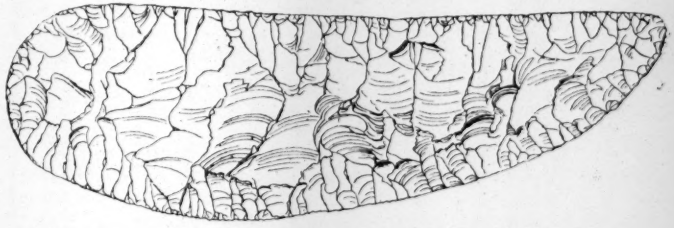


FIG. 7.—Chipped knife of chert, Sheikh Hamadeh, Egypt. (Fig. 101, p. 95 of Guide.) $\frac{1}{2}$ nat. size.

"We may draw similar conclusions from a consideration of the stone implements of the most primitive savage tribes. The knives of the now extinct Tasmanian aborigines were of the rudest description, generally chipped only on one side, and quite devoid of symmetry. The Andamanese had implements of a yet more elementary kind, and the Semang, a similar negrito tribe of the Malay Peninsula, are said only to have stone implements in the

sense that they pick up and use such convenient fragments as they may chance to find, usually employing shell, bamboo, or wood to provide for their simple needs. There are therefore still in existence peoples to whom, from climatic and other reasons, stone implements are of only secondary importance; and though

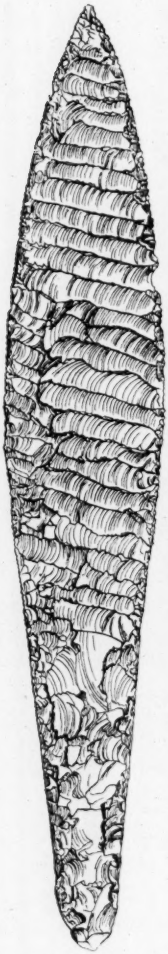


Fig. 8.—Flint knife, Denmark. (Fig. 115, p. 103 of Guide.) $\frac{1}{3}$ nat. size.

Fig. 9.—Unground axe-head, Hitcham, Bucks. (Fig. 121, p. 106 of Guide.) $\frac{1}{2}$ nat. size.

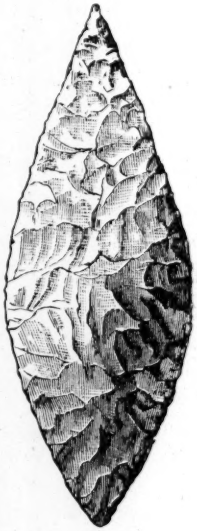


Fig. 10.—Flint javelin-head, long barrow, Wilts. (Fig. 138, p. 114 of Guide.)

their civilization is low, it must be higher than that of the earliest representatives of the human race. Yet supposing the negrito tribes had died out before their countries had been discovered by Europeans, the extremely rough character of their stone tools would probably have led anthropologists to reject them as of human

handiwork, or to assume that they were made by anthropoid apes. The search for evidence of man's existence before the drift-gravels of the present river-systems of Western Europe were deposited is, at any rate, justified by analogy, though how long before, zoology and anthropology must decide. What is quite certain is that the extreme rudeness of a chipped flint is not in itself a ground for its rejection as the work of man." (p. 11.)

The time and space at our disposal will not permit us to do adequate justice to Mr. Read's excellent Guide, which must certainly take a foremost place among such works, of which the Museums of Bloomsbury and Cromwell Road now possess a most admirable series.

We have borrowed only 10 out of the 199 illustrations which adorn this work, 142 being given in the text, while 57 half-tone figures make up ten beautifully printed process plates. The illustrations are for the most part original, and give examples of weapons of every form, country, and stage of development in the Age of Stone. Polishing appears to mark the later and more advanced period of culture, but when we examine the exquisite workmanship of the chipped and unpolished chert knives from Egypt, one is led to marvel at the very fine art in the manufacture of weapons in flint to which the ancient Egyptians must have attained before they were able to fabricate such lovely knife-blades in silex. In addition to several geological sections and views of ancient and modern pile-dwellings, there are about twenty drawings of carved bones, and pictures of animals on bone, given to complete this charming little book on the 'Stone Age.'

We have but to add that the price is only one shilling and everyone, we feel sure, will buy a copy.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—March 11th, 1903.—Prof. C. Lapworth, LL.D., F.R.S., President, in the Chair. The following communications were read :—

1. "Petrological Notes on Rocks from Southern Abyssinia collected by Dr. Reginald Kœttlitz." By Catherine A. Raisin, D.Sc. (Communicated by Professor T. G. Bonney, D.Sc., F.R.S., F.G.S.)

The specimens described in this paper were collected by Dr. Kœttlitz on an expedition (in 1898–99), starting from Berbera, westward through Somaliland and Southern Abyssinia, and turning northward to the Blue Nile. The paper gives petrological notes on the different classes of rocks represented. The crystalline rocks include granite, gneiss, and hornblende-schist or foliated diorite, together with more basic types. They occur where the plateau rises from the coastal plain, farther west underlying volcanic rocks and sedimentary strata, in the south-west of Abyssinia, and towards the Sudan. Some of the gneisses exhibit pressure effects, as if these older masses had been thrust up. The more basic types include diabase, hornblende-gabbro, and one lustre-mottled hornblende-pyroxenite, resembling a picrite.

The sandstones (which are chiefly from Somaliland and the south-east of Abyssinia) are sometimes compacted into quartzites, and are often ferruginous. Some of the limestones are concretionary, others are dolomitic, and several from different localities are fossiliferous, containing foraminifera, calcareous algæ, and, at Jigjiga Pass (which leads into Abyssinia), *Turritellæ* in great numbers.

The numerous specimens of volcanic rocks include one which is practically a limburgite, many basalts (a few with olivine, and some glassy), various less basic volcanic rocks, and several pumiceous tuffs. But the most interesting are the phonolites and allied rocks, containing nepheline, riebeckite, or other alkaline minerals. They occur at several places, one being a volcanic hill with a summit-crater. The authoress distinguishes several types among these soda-bearing rocks, and compares two of them with rocks of Central Abyssinia and of British East Africa respectively. Thus the specimens here described may form a connecting link between the volcanic rocks of other East African localities.

2. "The Overthrust Torridonian Rocks of the Isle of Rum and the Associated Gneisses." By Alfred Harker, Esq., M.A., F.R.S., F.G.S. (Communicated by permission of the Director of H.M. Geological Survey.)

The Torridonian strata of Rum occupy all the northern part of the island, together with a strip extending along the eastern coast, the high ground in the south being made by plutonic rocks of Tertiary age. The northern tract consists in general of sandstones having a moderate dip to the north-west or west-north-west, and below these there emerges on the east side a lower group composed of dark shales. There are, however, two districts in which the strata are highly disturbed and overthrust. One is a small area to the north-west, on Monadh Dubh, where a cake of thoroughly brecciated and mylonitized rocks rests on the relatively unmoved sandstones. Besides sandstone, this crushed mass contains abundant débris of Cambrian limestone, chiefly towards the base, and resting immediately upon the surface of overthrust. The limestone does not occur in place on the island.

The other and more extensive area of overthrust rocks forms a belt along the north-eastern and eastern border of the mountain tract. The effect of the displacement has been to bring the shales of the lower group to rest on the sandstones of the upper. Above the main surface of movement the shales are violently contorted, and the sandstones, where these occur, brecciated. There is also considerable thermal metamorphism, due to the Tertiary intrusions. At numerous places along the disturbed belt are patches and lenticles of gneiss. These are intrusive in the Torridonian rocks, and the evidence points to their being of Tertiary age. They have arisen in great part from a granitic magma modified in varying degree by dissolving basic, and often ultra-basic, rock-débris. The heterogeneous composition thus imparted has, with flowing movement, resulted in a well-marked gneissic banding. In a minor degree basic rocks, probably gabbros originally, have contributed more directly

to the composition of the complex, namely, as bands or lenticles of rocks, now hornblendic, representing distinct intrusions enveloped and modified by the later and more voluminous invasion of acid magma.

The chief conclusions which the author wishes to establish are :—

(i) That the highly disturbed region of the North-West Highlands, already known to extend into the south-eastern part of Skye, is further prolonged into the Isle of Rum.

(ii) That at numerous places along the disturbed belt which borders the principal mountain group of the island, the Tertiary plutonic intrusions assume the character of well-banded gneisses, comprising alterations of different lithological types.

(iii) That these complex gneisses were formed mainly by fluxion in a heterogeneous mass, the heterogeneity being due to the inclusion and incorporation in a granitic magma of relics of ultra-basic and basic rocks.

II. — March 25th, 1903. — Professor Charles Lapworth, LL.D., F.R.S., President, in the Chair. The following communications were read :—

1. "On a New Species of *Solenopsis* from the Pendleside Series of Hodder Place, Stonyhurst (Lancashire)." By Wheelton Hind, M.D., F.R.C.S., F.G.S.

This specimen of a perfect left valve was found by the Rev. Charles Hildreth in shales belonging to the Pendleside Series, which have yielded the following fossils: *Phillipsia Van-der-Grachtii, Ph. Polleni, Prolecanites compressus, Glyptoceras spirale, Gl. reticulatum, Gl. platylobium, Orthoceras annulosolineatum, Posidonomya Becheri, Solenopsis major,* and a few Brachiopods.

2. "Note on some *Dictyonema*-like Organisms from the Pendleside Series of Pendle Hill and Poolvash." By Wheelton Hind, M.D., F.R.C.S., F.G.S.

Mr. D. Tate discovered a specimen, in the shales and limestones in the Angram Brook, which had some resemblance to a *Dictyonema*; and he afterwards found another similar specimen, on or about the same horizon, at Poolvash. These are referred to distinct species, and doubtfully assigned to the genus *Dictyonema*. A piece of shale from the Bishopton Beds in Glamorganshire has somewhat similar but less distinctly reticulate markings.

3. "The Geology of Tintagel and Davidstow District (Northern Cornwall)." By John Parkinson, Esq., F.G.S.

The country described and mapped consists of some 22 square miles in Northern Cornwall, extending from the coast eastward towards Camelford Station and St. Clether. In the eastern part it extends to the neighbourhood of the Brown Willy mass of granite, while on the north it approaches the boundary between the Lower Culm and the Upper Devonian. The rocks described are of the latter age, and contain *Spirifera disjuncta.*

Except in the southern coast region (Tintagel and Trebarwith Strand) the strike is fairly uniform in an east-south-easterly and west-north-westerly direction, the beds having a northerly dip;

but north and south of Tintagel Head the higher members appear, greatly faulted, being brought in out of their true position partly by a change of strike, partly by dip-faults. The most distinctive rocks, utilized as a datum for mapping, are a group of ashes and lavas. The latter are often amygdaloidal, and possess original characters which are still recognizable; but the whole group is frequently much altered or entirely reconstructed, with the formation of epidote (sometimes enclosing allanite), sphene, biotite, chlorite, etc. The rocks are associated in many instances with calcite, at least partly due to contemporaneous deposition, but frequently forming a corporate part of the renovated rock, and the mineral is found with quartz and translucent felspar.

Bluish-black slates and finally laminated quartzose beds overlie and underlie this volcanic series.

The remaining rocks are phyllites, closely resembling those from the Ardennes. The author divides them into four groups. The highest of these (Tredorn Beds) overlies the uppermost division of the Blue-Black slates, and in the western part of the district contains a mineral forming small white spots, not yet determined. The beds underlying the Lower Blue-Black slates (Halwell Cottage Beds) are banded phyllites, with quartzose laminæ, typically containing abundant crystals of clinochlore with a habit resembling that of ottrelite. The underlying phyllites (Penpethy Beds and Slaughterbridge Beds) contain no distinctive mineral. Taken as a whole, the phyllites consist of a sericitic and chloritic groundmass containing unorientated crystals of white mica, micaceous ilmenite, hæmatite, and minor quantities of tourmaline and rutile. North-east of Camelford (Grigg's Down) they furnish clear evidence of contact-metamorphism.

III. — April 8th, 1903. — J. J. H. Teall, Esq., M.A., F.R.S., Vice-President, in the Chair.

Professor W. W. Watts drew attention to the exhibit on the table of the new series of Platinotype Photographs issued by the Geological Photographs Committee of the British Association.

The following communications were read :—

1. "On the Probable Source of some of the Pebbles of the Triassic Pebble-Beds of South Devon and of the Midland Counties." By Octavius Albert Shrubsole, Esq., F.G.S.

After an account of previous researches on this subject, the author proceeds to describe the Budleigh Salterton Pebble-Beds. Judging from lithological evidence, the bulk of the pebbles must have come from a definite region of a comparatively simple geological character; and this is confirmed by the palæontological evidence. The supposition is natural that Devonian rocks were once represented either in the Calvados district or in some region in the same drainage area as that which has supplied the Ordovician element. The Grès de May of Normandy and its associated rocks are next described, a massif which, according to Professor Bonney, must have exceeded the Alps in breadth. When regard is had to the extent and original thickness of the Grès de May, it appears capable

of furnishing abundant material, not only for the Ordovician pebbles of the Budleigh Salterton Pebble-Bed, but also for a great deal more. A list of species common to the Grès de May, of May itself, and the Budleigh Salterton deposit is given; and it is pointed out that in the Department of the Manche the former deposit varies in palæontological facies. In addition to the identity of the quartzites and felspathic grit in the two areas, it is noted that the so-called lydianstone (tourmaline-grit) of Budleigh and the Midlands may be paralleled with one referred to by MM. de Tromelin and Lebesconte in the Department of Maine-et-Loire. The author is struck with the resemblance of the Midland Bunter to that of Devon, and he gives the percentage of rock-types in the larger pebbles at Repton and in the smaller material of Drift derived from the Bunter at two localities in the Lickey Hills. Strong family likenesses subsist between certain specimens in the northern and southern Bunter and some of the undisturbed rocks of Normandy. A list of fossils from the Midland Bunter contains three southern forms; and a further table is given comparing fossils from Drift-pebbles from Budleigh Salterton and from Normandy. Fourteen out of twenty of the Drift and Bunter fossils are found at Budleigh Salterton and in Normandy. The hypothesis which presents the least difficulty appears to be that which regards the two pebbly deposits, north and south, as having had approximately a common origin. It does not necessarily follow that both deposits are due to the same river.

2. "Note on the occurrence of Keisley Limestone Pebbles in the Red Sandstone Rocks of Peel (Isle of Man)." By E. Leonard Gill, Esq., B.Sc. (Communicated by Prof. W. Boyd Dawkins, D.Sc., F.R.S., F.S.A., F.G.S.)

Pebbles of a coarsely crystalline, greyish-white, mottled limestone, collected by Prof. W. Boyd Dawkins from the conglomerates at Whitestrand, contain the following fossils: *Illænus Bowmanni*, var. *brevicapitatus*, *Primitia Maccoyi*, *Orthis calligramma*, *O. testudinaria*, *O. biforata*, *Rafinesquina deltoidea*, *Plectambonites quinquecostata*, *Atrypa expansa*, *Hyatella Portlockiana*, *Dayia pentagonalis*, *Platyceras verisimile*, *Stenopora fibrosa*, and crinoid stems. This assemblage of fossils corresponds strikingly with that of the Keisley Limestone; and it is therefore concluded that the pebbles have been derived from that rock. It seems hardly likely that they have come from so distant a locality as the Lake District; more probably there has been a local source, which would form a link between the limestone of Keisley and that of the Chair of Kildare.

CORRESPONDENCE.

THE *GEOLOGISCHES CENTRALBLATT*.

Sir,—Dr. Keilhack's invitation to authors to supply their own abstracts comes none too soon; it is to be hoped that this plan will prevent the mistakes which are apt to occur under the present régime. In the current number (March) two papers by myself on the Crystalline Limestones of Ceylon are reviewed. The abstract of